Minnesota Wild Rice Research 1981

Agricultural Experiment Station
University of Minnesota
St. Paul, Minnesota 55108
January 16, 1982

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Most of the research reported here is preliminary, thus the results should be interpreted with caution and should not be used in publications unless arrangements are made with the authors.

The wild rice team wishes to acknowledge the assistance provided by many people. The cooperation of Dr. Rust, Superintendent of the North Central Experiment Station, Grand Rapids and Dr. Wilcox, Superintendent of the Rosemount Experiment Station was greatly appreciated. The use of facilities at the Horticultural Research Center at Excelsior was appreciated. Also, the help of Drs. Rabas and Boedicker at the North Central Experiment Station, Grand Rapids was highly appreciated. The daily supervision of the research plots at Grand Rapids by Henry Schumer, Research Plot Supervisor, was very valuable. We are also extremely grateful to the growers and processors for providing seed, land area and equipment for research. We thank Deerwood Wild Rice Processing, Inc. for the funds provided in 1981 to the Agricultural Engineering Department for processing research. Some improvements and expansion of research paddy areas were done in 1981. The research paddy area for plant breeding at Rosemount was increased and electricity is now available at Grand Rapids. We appreciate the continued support of the Agricultural Experiment Station for wild rice research.

WILD RICE FERTILIZATION RESEARCH - 1981

A PROGRESS REPORT
December 29, 1981

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Research was continued during 1981 on fertilization and nutrient requirement of wild rice. Soil, water and air temperatures, and quality of paddy water were monitored during the growing season at several locations to obtain information on the environment in which wild rice grows. A nitrogen experiment was conducted with the Netum variety on a mineral soil at Grand Rapids. A fertilization trial with the K2 variety was conducted on peat in Aitkin County. Tissue samples were collected for plant analysis to learn more about nutrient uptake by the plant.

A. WEATHER CONDITIONS AND PLANT DEVELOPMENT

Average temperatures recorded at four U.S. weather stations were slightly above normal in April and remained near normal during the main part of the growing season (Table 1).

Soil, water and air temperatures were measured at four locations by automatic sensing and recording thermographs (see Fig. 1, 2, 3, 4). Soil and water temperatures were not recorded at Gully because of an instrument malfunction.

Plants emerged on May 4 at Grand Rapids (Fig. 5). The jointing stage was reached by Netum on June 21, 48 days after plant emergence. Wild rice was harvested on August 12, 100 days after emergence. Accumulated Growing Degree Days (GDD) at each stage of plant development was calculated with a base temperature of 40°F. Accumulated GDD's for the 1981 season were 2,247, while total solar radiation for the season at Grand Rapids reached 36,745 langleys or calories per square centimeter.

Table 1. Average air temperature as measured at four U.S. weather stations.[1/]

Station Year	April	May	June	July	August	5 Month Average	GDD T_b=40
	----------	----average air	temperature, °F	----------			
Fosston, Polk Co.							
Normal[2/]	41.0	54.6	63.6	69.4	67.5	59.2	2955
1974	41.0	50.5	63.4	71.6	62.8	57.9	2744
1975	34.8	55.7	61.9	70.5	64.6	57.5	2852
1976	46.6	54.9	66.8	68.8	70.9	61.6	3315
1977	49.1	66.4	64.6	70.3	60.6	62.2	3446
1978	41.7	59.2	63.4	67.8	67.7	60.0	3060
1979	36.0	48.7	63.6	69.6	63.6	56.3	2627
1980	48.9	61.3M[3/]	68.5	71.0	64.6	62.9	3466
1981	44.4	55.3	60.8	68.1	65.7	58.8	2898
Grand Rapids, N.C. School							
Normal	39.9	52.7	62.0	67.4	65.1	57.4	2681
1974	41.6	49.4	62.7	70.7	62.8	57.4	2670
1975	34.7	57.0	62.2	71.5	65.2	58.1	2951
1976	47.1	54.4	66.1	68.2	67.4	60.6	3166
1977	48.2	63.8	64.0	69.2	60.2	61.1	3284
1978	41.3	57.9	62.8	66.5	66.0	58.9	2892
1979	37.1	49.5	61.5	68.1	62.6	55.8	2511
1980	46.1	59.9	64.0	69.0	66.4	61.1	3237
1981	43.9	54.8	62.0	68.0	67.0	59.1	2941
Aitkin							
1974	42.9	49.8	63.1	71.1	63.3	58.0	2770
1975	39.0M	59.4M	64.4M	72.1	66.2M	60.2	3141
1976	47.5	54.8	66.8	69.3M	68.1	61.3	3267
1977	48.3M	64.4M	65.4M	70.3M	61.0	61.9	3446
1978	40.7M	57.5M	64.1M	67.0M	66.9	59.2	2938
1979	37.7	50.6	62.0	68.1M	63.4	56.4	2585
1980	53.9	58.3	64.0	68.5	66.0	62.1	3394
1981	45.1M	53.8	62.1M	67.5	66.0	58.9	2902
Chaska, Carver County							
Normal[4/]	45.9	58.1	67.8	72.4	70.7	62.9	3528
1981	51.3	57.9	67.8	73.5	70.6	64.2	3715

1/ Source: Climatological Data, Minnesota, Vol. 80-87 (1974-81), U.S. Dept. of Commerce.
2/ Normals for the period 1931-1960.
3/ M = less than 10 days record missing.
4/ Normals for the period 1941-1970.

Fig. 1

MEAN AIR, WATER AND SOIL TEMPERATURES
GRAND RAPIDS - 1981

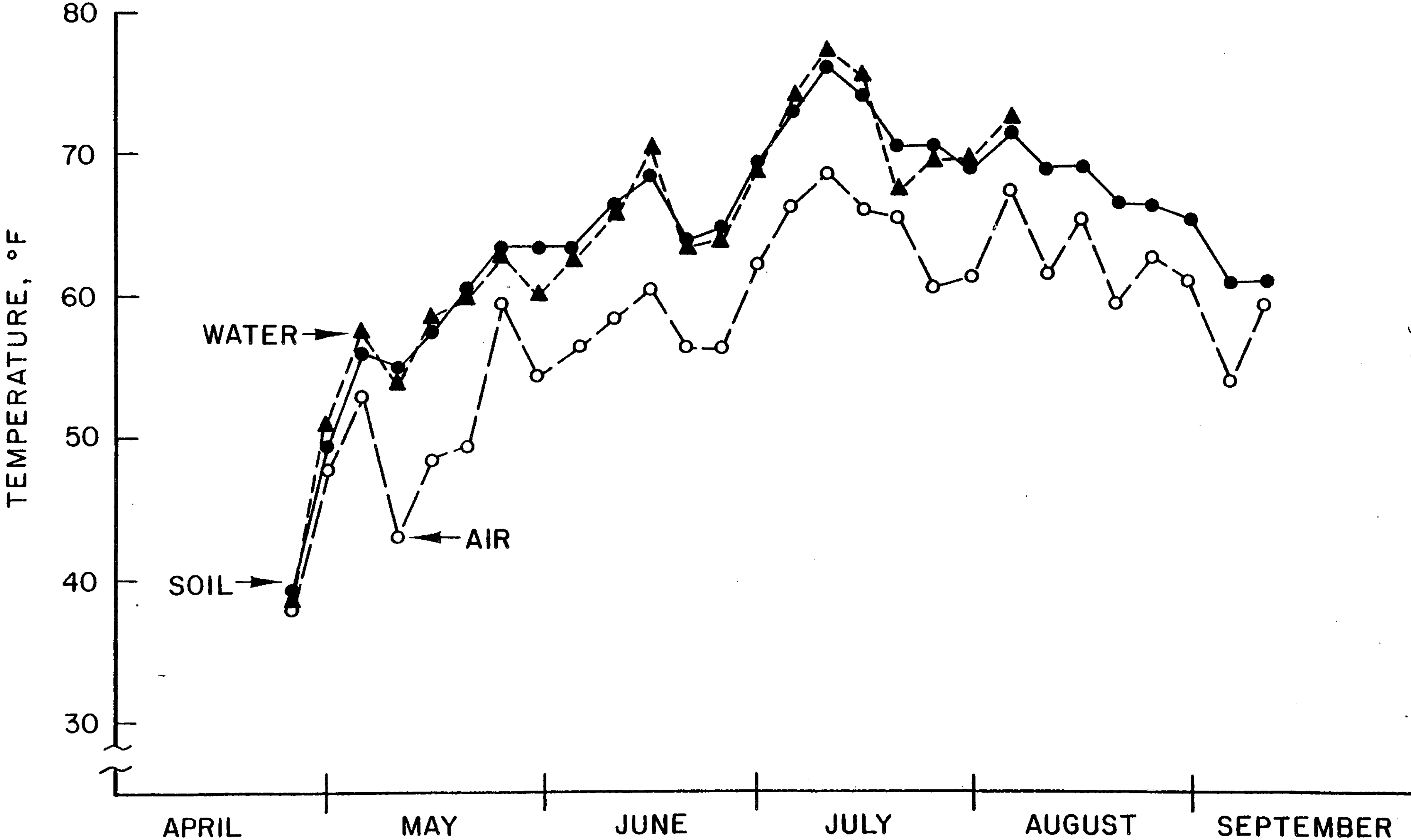

Fig. 2

MEAN AIR, WATER AND SOIL TEMPERATURES
KOSBAU BROS., AITKIN COUNTY - 1981

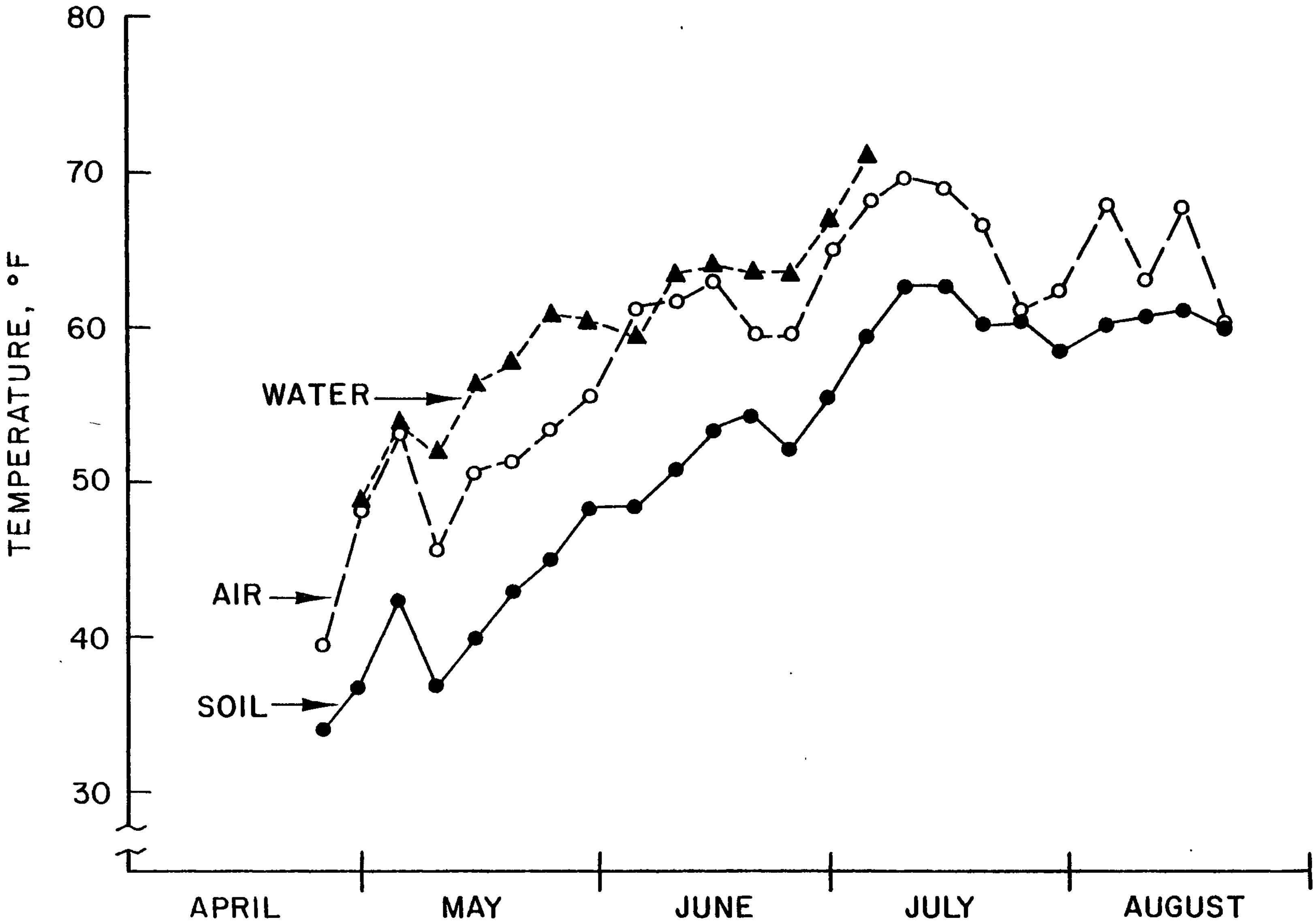

Fig. 3

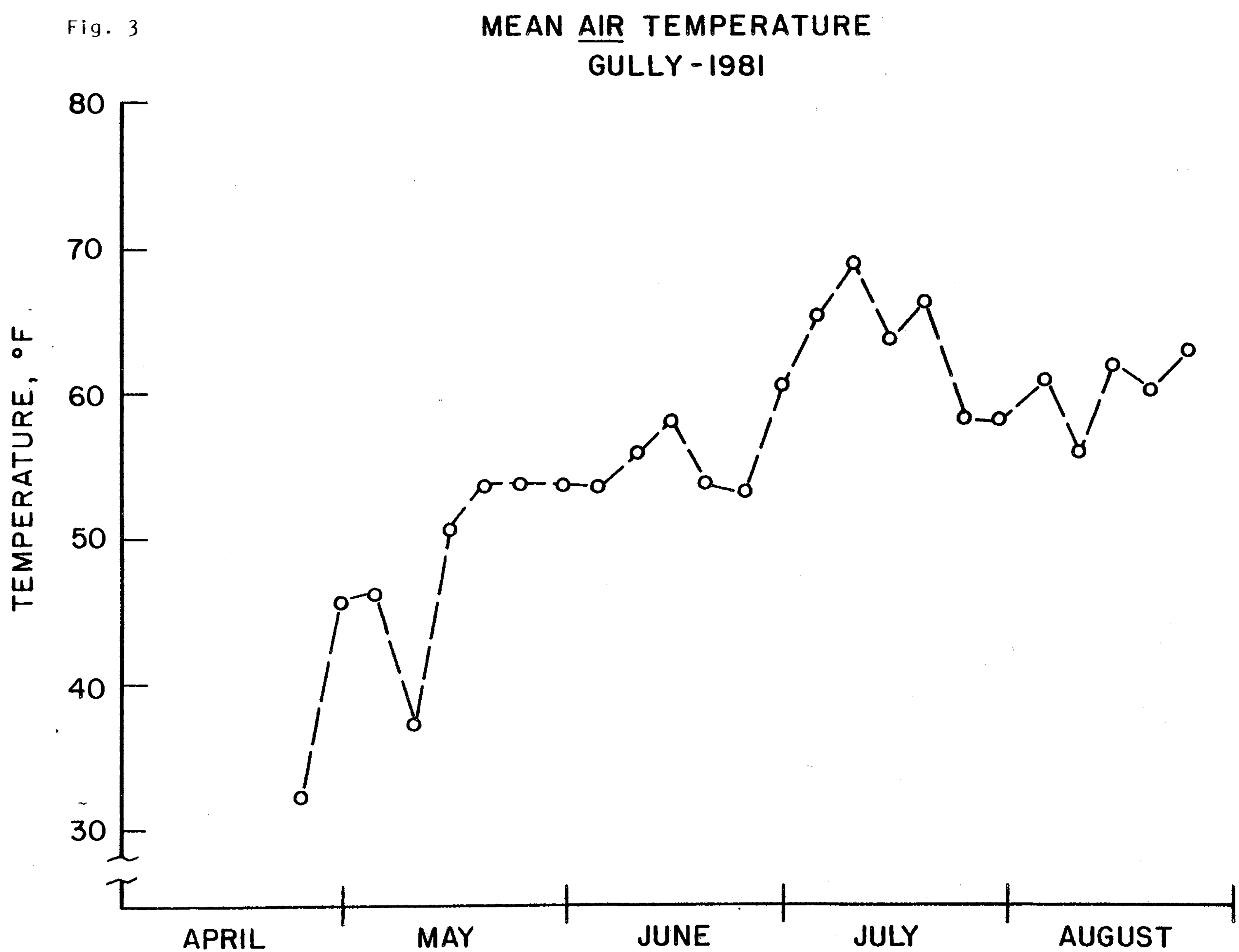
MEAN AIR TEMPERATURE
GULLY - 1981
TEMPERATURE, °F
80
70
60
50
40
30
APRIL
MAY
JUNE
JULY
AUGUST

Fig. 4

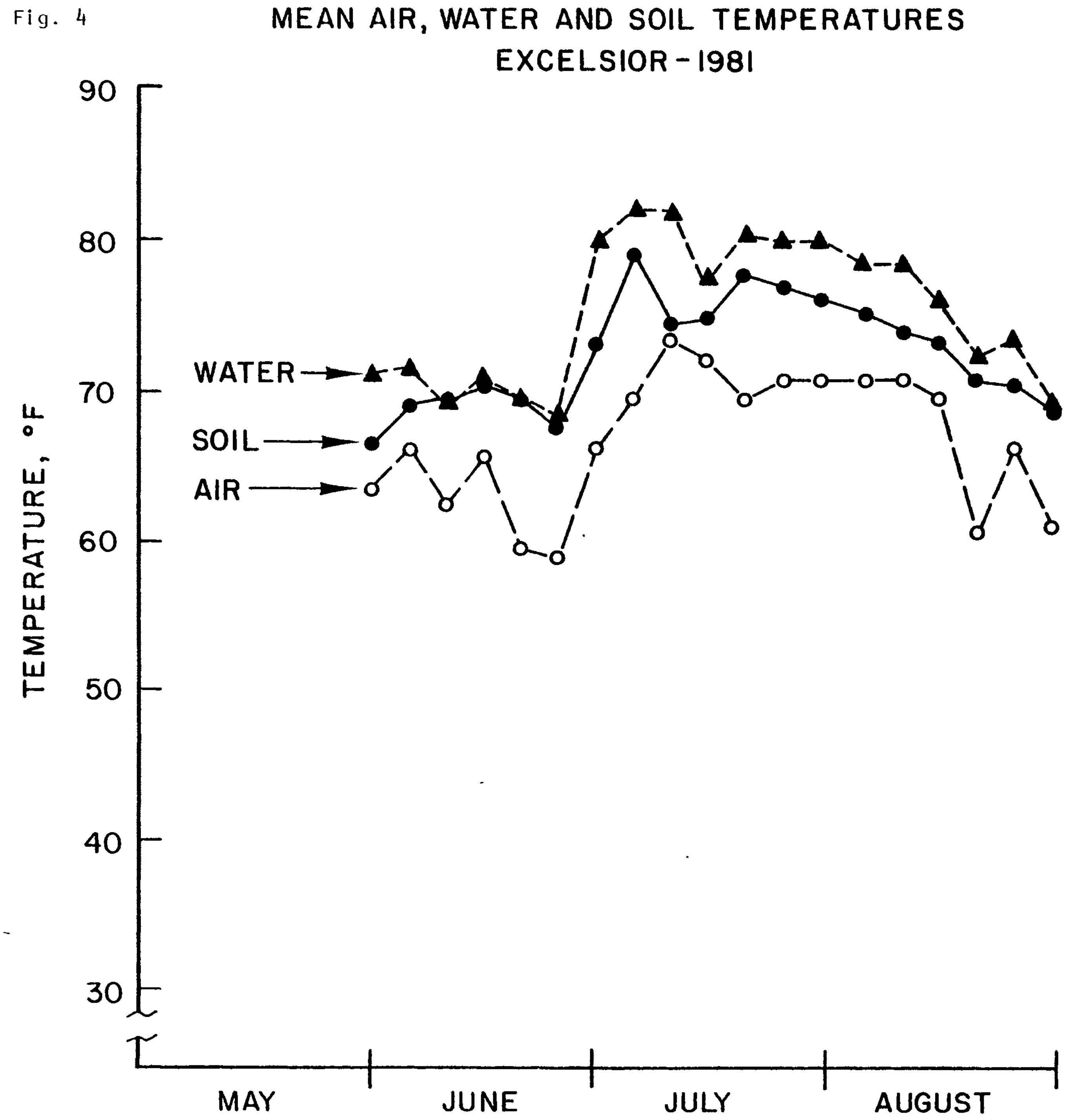
MEAN AIR, WATER AND SOIL TEMPERATURES
EXCELSIOR - 1981
TEMPERATURE, °F
90
80
70
60
50
40
30
WATER
SOIL
AIR
MAY
JUNE
JULY
AUGUST

Fig. 5

WILD RICE DEVELOPMENT
NETUM VARIETY, 2ND YEAR STAND
GRAND RAPIDS, 1981

	STAGES OF DEVELOPMENT	DAYS	DATE	1/ GDD	2/ SOLAR
VEGETATIVE GROWTH PHASE	EMERGENCE	0		0	0
	FLOATING LEAF	14	MAY	151	6273
	AERIAL LEAF	32		495	12442
	TILLERING	44	JUNE	774	17021
REPRODUCTIVE GROWTH PHASE	JOINTING	48		855	18306
	BOOT	52		932	19288
	HEADING	61		1152	23097
	MID-FLOWERING	67	JULY	1349	26329
	LATE-FLOWERING	73		1533	27903
	MATURITY	100	AUGUST	2247	36745

1/ - ACCUMULATED GROWING DEGREE DAYS, $T_b = 40°F$

2/ - SOLAR RADIATION ACCUMULATED, LANGLEYS PER DAY (CAL, CM^{-2})

B. CHEMICAL CHARACTERISTICS OF PADDY WATER

Water samples were collected at three different paddy locations during the 1981 growing season. At Grand Rapids, samples were collected from an experimental paddy used for nitrogen studies on mineral soil, and from the Prairie River which was the source of water. Water was also sampled within a production paddy in Aitkin County. Paddies at this site derived water from the Little Willow River via a diversion ditch. The third sampling site was in the Imle and Gunvalson paddies near Gully. This paddy derived water from the Clearwater River.

Water samples were collected and stored in 250 ml polyethylene bottles, with a preservative added (2 ml mercuric chloride solution, prepared by dissolving 40 mg $HgCl_2$/L, to 250 ml of sample). Chemical analyses were made by the Research Analytical Laboratory, University of Minnesota. Information on location, sampling dates, and chemical composition data of water is given in Table 2.

The <u>hardness</u> of water is a measurement of calcium and magnesium, expressed as $CaCO_3$, mg/liter. The water from the Clearwater River was very hard (348-389 mg/L). The water from the Prairie River and the Little Willow River was moderately hard, with values near 80 mg/L. At Gully and Grand Rapids, the levels of hardness, calcium and magnesium of paddy water were nearly the same as those found in the river water. In Aitkin County on peat, however, the paddy water showed 25 to 37% lower calcium and 28 to 58% lower magnesium content than the river water, and a 3-fold decrease in the hardness. Consequently, the water within the Kosbau paddy in Aitkin County was relatively soft, having values of 26 to 36 mg/liter.

At Grand Rapids, concentrations of total P, and K in paddy and river water were nearly the same. The paddy water, however, had slightly higher total N concentration than found in the river water.

At Gully, no difference was detected in the total P concentration of river and paddy water. The paddy water, however, had slightly higher concentration of total N, and K than river water. Nitrogen and potassium concentrations in samples of July 2 sampling appeared to be inconsistent.

The paddy water of the Aitkin County location had considerably higher concentrations of total N, P, and K than found in the river water. This was consistent with the results of nutrient concentrations obtained at this location during previous growing seasons.

The sulfate concentration of water is reported in terms of parts per million of sulfate- sulfur, expressed as S. To convert results to the sulfate (SO_4) form, they must be multiplied by 3. For example, 1.2 ppm sulfate-S x 3 = 3.6 ppm sulfate (SO_4) in the water.

The water at Grand Rapids and in Aitkin County, generally, contained less than 10 ppm of sulfate. The sulfate concentration of the water at Gully, however, was relatively high (80 to 192 ppm SO_4).

Table 2. Chemical composition of water collected from wild rice paddies during 1981 growing season.

Sample No.	Sampling Date	Location	Conductivity millimhos/cm	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm	Na ppm
Location: Grand Rapids														
14-2	4/22	EP-W	0.19	60.0	83.0	0.7	0.08	0.01	0.01	1.2	22.2	6.4	2.5	3.1
14-1	4/22	PR	0.20	65.0	86.0	0.3	0.16	0.02	0.02	1.3	23.6	6.5	3.0	3.2
23-2	5/26	EP-W	-	52.0	64.3	0.6	<0.05	0.07	0.01	1.7	18.1	4.2	0.9	1.8
23-1	5/26	PR	-	55.5	74.7	0.5	<0.05	0.07	0.01	2.4	20.1	5.8	1.7	2.8
25-3	6/9	EP-W	0.16	64.0	75.2	1.3	<0.05	0.10	0.02	2.2	19.9	5.6	1.1	2.6
25-4	6/9	PR	0.13	70.5	79.2	0.4	<0.05	0.07	0.01	2.6	21.7	5.9	1.4	2.7
28-3	6/23	EP-W	0.16	69.5	80.7	0.4	<0.05	0.15	0.01	2.1	21.3	6.1	1.1	2.9
28-4	6/23	PR	0.20	68.5	82.0	1.3	<0.05	0.14	0.02	2.4	22.4	6.2	1.5	3.0
43-6	7/7	EP-W	0.18	-	-	2.9	-	0.09	-	-	21.6	5.9	2.0	4.1
43-5	7/7	PR	0.16	-	-	3.3	-	0.08	-	-	22.1	6.0	1.2	3.0
43-7	7/23	EP-W	0.22	-	-	2.0	-	0.13	-	-	23.3	6.6	1.9	3.2
43-8	7/23	PR	0.18	-	-	0.7	-	0.08	-	-	23.4	6.6	1.5	3.4
43-10	7/31	EP-W	0.16	-	-	2.0	-	0.07	-	-	21.6	5.9	1.0	2.7
43-9	7/31	PR	0.16	-	-	0.6	-	0.07	-	-	22.2	6.2	1.0	3.1

Abbreviations and descriptions of sampling sites at Grand Rapids: EP-W = Experimental Paddy #1 West; PR = Prairie River

Table 2 continued.

Sample No.	Sampling Date	Location	Conductivity millimhos/cm	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm	Na ppm
Location: Kosbau Bros., Aitkin Co.														
14-6	4/23	PP	0.11	25.0	26.0	2.1	<0.05	0.74	0.54	2.2	5.7	2.2	8.9	4.5
14-5	4/23	DD	0.22	80.0	91.0	0.7	0.05	0.02	0.02	1.6	22.9	7.8	1.4	4.3
23-4	5/26	PP	-	20.5	36.5	2.3	<0.05	1.08	0.71	3.1	8.4	3.5	7.4	4.9
23-3	5/26	DD	-	67.0	83.3	1.3	<0.05	0.07	0.01	1.7	22.8	6.0	0.7	2.9
25-1	6/9	PP	0.12	15.5	36.4	2.5	<0.05	1.47	1.24	3.4	8.2	3.5	6.2	4.8
25-2	6/9	DD	0.18	79.5	89.4	1.1	<0.05	0.16	0.04	2.7	22.7	7.5	0.7	4.2
28-2	6/23	PP	<0.10	9.0	28.8	1.9	<0.05	1.59	1.19	3.4	6.4	2.8	4.5	3.5
28-1	6/23	DD	0.16	63.0	84.1	1.0	<0.05	0.09	0.02	3.1	21.4	6.8	0.5	3.1
43-3	7/7	PP	0.10	-	-	9.2	-	1.86	-	-	8.9	4.3	4.5	4.2
43-4	7/7	DD	0.20	-	-	1.2	-	0.15	-	-	26.8	8.2	<0.5	3.9

Abbreviations and descriptions of sampling sites at Kosbau Bros.: PP = Production Paddy; DD = Diversion Ditch at bridge near the Little Willow River

Sample No.	Sampling Date	Location	Conductivity millimhos/cm	Alkalinity as $CaCO_3$ mg/L	Hardness $CaCO_3$ mg/L	Total Kjeldahl N ppm	Nitrate & nitrite N ppm	Total P ppm	Soluble P ppm	Sulfate S ppm	Ca ppm	Mg ppm	K ppm	Na ppm
Location: Imle and Gunvalson, Gully														
14-4	4/22	PP	0.72	170.0	352.0	1.6	<0.05	0.07	0.04	48.8	88.1	31.9	9.2	8.4
14-3	4/22	CR	0.75	300.0	389.0	1.0	<0.05	0.06	0.04	36.3	96.7	35.7	6.7	9.3
28-8	5/14	PP	0.90	269.0	474.0	1.8	<0.05	0.14	0.05	64.0	121.0	41.5	11.5	11.9
28-7	5/14	CR	0.75	262.0	348.0	1.2	<0.05	0.15	0.05	26.6	86.0	32.0	4.6	9.0
43-1	7/2	PP	0.55	-	-	16.7	-	0.11	-	-	71.1	30.0	0.8	7.5
43-2	7/2	CR	0.50	-	-	3.4	-	0.13	-	-	66.3	25.8	2.4	6.2

Abbreviations and descriptions of sampling sites at Gully: PP = Production Paddy; CR = Clearwater River

C. NITROGEN STUDIES ON MINERAL SOIL

The nitrogen rate and time of application trial, initiated in fall of 1979, was continued with 2nd year stand of Netum in paddy No. 1 West at the North Central Experiment Station, Grand Rapids. Soil tests (Table 3) indicated very high levels of extractable phosphorus (59 pp2m) and exchangeable potassium (303 pp2m). It should be noted that the experimental area had not received any phosphate or potash fertilizer since the establishment of the paddy in 1974. It has been a common practice, however, to incorporate wild rice stubble into the soil.

Nitrogen treatments consisted of four rates (0, 20, 40, 80 lb N/acre) applied in single (fall) or split-applications (½ fall + ½ jointing, or ½ fall + ½ early flowering). Urea (46-0-0) was the source of nitrogen. Fall-application of urea was made on November 6, 1980 and the fertilizer was incorporated into the soil by rototilling. Additional N was topdressed by hand at jointing or early flowering. A randomized block design was used in this experiment. Each treatment was replicated four times. Individual plots occupied a 14 x 16 ft. area and were separated from adjoining plots by 5 ft. wide alleys. Plant density, at harvest, ranged from 1 to 3 plants per square foot. Water level was maintained at about 6 to 10 inches. Five plants were collected at random from each plot at late flowering for weight measurement and plant analysis. The jointing stage was reached on June 21 (Fig. 5). A 32 sq. ft. area from each plot was hand-harvested on August 12 for yield determination.

Individual plants at late flowering had accumulated 4 to 6 grams of dry matter and 63 to 86 milligrams of nitrogen (Table 4).

Netum grain yields (7% moisture) ranged from 280 to 538 pounds per acre (Table 5). The yield, however, was increased above the check only by two N treatments, namely, 40 lb/A (fall) and 80 lb/A (½ fall + ½ early flowering).

Table 3. Soil test values of experimental paddy No. 1 West, Grand Rapids.[1)]

pH	Extractable P pp2m	Exchangeable K pp2m	Nitrate-N lb/A
6.2[2)]	59	303	12

1) Samples collected from 0-6 inch depth on 11/6/80.

2) Average of four composite samples.

Table 4. Effect of nitrogen application on total uptake of N by Netum wild rice, 2nd year stand, Grand Rapids, 1981.

Treatment No.	N Rate lb/acre	Time of Application: Fall	Time of Application: Jointing	Time of Application: Early Flowering	N Uptake[1)] mg/plant
		---------N lb/acre---------			
1	0	-	-	-	71
2	20	20	-	-	63
3	40	40	-	-	86
4	40	20	20	-	85
5	40	20	-	20	65
6	80	80	-	-	85
7	80	40	40	-	77
8	80	40	-	40	73
Significance					ns
C.V. (%)					39

1) Average of four replications.

Table 5. Effect of nitrogen application on the yield of Netum wild rice, 2nd year stand, Grand Rapids, 1981.

Treatment No.	N Rate lb/acre	Time of Application: Fall	Time of Application: Jointing	Time of Application: Early Flowering	Grain Yield[1)] lb/acre
		---------N lb/acre---------			
1	0	-	-	-	311
2	20	20	-	-	280
3	40	40	-	-	538
4	40	20	20	-	335
5	40	20	-	20	401
6	80	80	-	-	476
7	80	40	40	-	380
8	80	40	-	40	502
Significance					+
BLSD (0.1)					171
C.V. (%)					29

1) At 7% moisture, average of four replications.

\+ Denotes significance at the 10% level.

D. FERTILIZATION STUDIES ON PEAT

A fertilizer experiment was conducted with the K2 variety of wild rice on organic soil in a Kosbau Bros. paddy in Aitkin County. Relatively high extractable phosphorus (25 pp2m), and medium exchangeable potassium (145 pp2m) levels were indicated by soil tests. The soil pH was 5.3. This was an incomplete factorial experiment with six NPK treatments, replicated six times, and arranged in randomized blocks. Individual plots occupied a 14 x 16 ft. area. Fertilizer materials (46-0-0, 0-46-0, 60-0-0) were applied by hand on October 8, 1980 and incorporated into the soil by disking.

Plants emerged on May 1 and reached the jointing stage on June 30. The paddy was drained on July 1.

The wild rice stand was extremely thin and spotty and the plants were short with only one or two tillers. The experimental area suffered from a heavy infestation by waterplantain which appeared to be related to a relatively shallow water level. On June 11, MCPA ($\frac{1}{4}$ lb/acre a.i.) was applied with a 10-foot boom. A 0.1 inch localized thundershower, several hours after application, may have removed much of the applied herbicide. Herbicide application did not effectively control waterplantain in the experimental area.

Because of extremely poor stand and growth of wild rice, only one row of plots on the east side of experiment (where the growth was best) was harvested on August 17 for yield determination. The grain yield (7% moisture) ranged from 96 to 164 pounds per acre. Average plant density, at harvest, was 2.5 plants per square foot. It should be noted that wild rice produced 392 to 555 lb/acre of grain in other areas within the same paddy with deeper water and little or no waterplantain.

ACKNOWLEDGMENTS

Grateful acknowledgments are made to the following cooperators and University personnel for their assistance during 1981 in obtaining the information reported here: Messrs. Franklin and Harold Kosbau, Aitkin County; Messrs. John Gunvalson and Paul Imle, East Polk County; the Staff of the North Central Experiment Station; Dr. E. A. Oelke, Messrs. Jeffrey Schmidt, Henry Schumer, Greg Spoden and Joel Ransom, University of Minnesota.

WILD RICE PRODUCTION RESEARCH - 1981

E.A. Oelke, J.K. Ransom, and M.J. McClellan
Department of Agronomy and Plant Genetics

Work continued this year on weed control, plant population, time of harvest, simulated hail damage, wild rice plant development as influenced by temperature and daylength, seed survival and seed storage. The work was conducted on University plot land in St. Paul and Grand Rapids and in growers' fields near Aitkin, Clearbrook and Waskish. Glasshouses and growth chambers at St. Paul were also utilized for some of the work. The early part of the 1981 growing season was conducive to good vegetative development but cloudy and rainy weather during flowering caused yield reductions due to less light and substantial leaf disease. However, total production was similar to 1980.

WEED RESEARCH

Herbicides

The herbicide trials in 1981 continued on the use of 2,4-D amine and MCPA in wild rice for control of common waterplantain. The trials were conducted at Grand Rapids, Aitkin and St. Paul.

Table 1 shows the combined 1980 and 1981 Grand Rapids data from trials conducted with 2,4-D amine and MCPA applied to common waterplantain from rootstocks at different growth stages. Both chemicals were applied at 1/4 and 1/2 lb/A a.i. (active ingredient) when common waterplantain was in the 2 aerial leaf, 6 aerial leaf, scape (flowering stem) elongation, and early flowering stages of growth. MCPA was more effective than 2,4-D amine for controlling common waterplantain regardless of growth stage. Percent common waterplantain control increased as herbicide applications were delayed until the scape elongation stage. These trials were conducted with common waterplantain grown without wild rice.

Table 1. Percent control of common waterplantain with 2,4-D amine and MCPA applied at four growth stages at Grand Rapids in 1980 and 1981.

Herbicide	Rate	Growth stage treated: 2 aerial leaf	6 aerial leaf	Scape elongation	Early flowering	Herbicide rate average
	lb/A a.i.	% Control				
2,4-D amine	1/4	7	0	7	13	7
2,4-D amine	1/2	9	16	37	18	20
MCPA	1/4	13	14	23	12	16
MCPA	1/2	15	31	60	53	40
Growth stage mean		11	15	32	24	

LSD .05 for herbicide rates within growth stages = 13

In 1981, additional trials were conducted where common waterplantain from rootstocks and wild rice were grown together and treated with 2,4-D amine and MCPA at 1/4 and 1/2 lb/A a.i. One trial was conducted at Grand Rapids where wild rice and common waterplantain were planted together and a second trial was conducted near Aitkin in a grower's field with a heavy infestation of common waterplantain in wild rice. Table 2 lists the results from Grand Rapids and Table 3 the results from Aitkin County.

Table 2. The influence of two rates of 2,4-D amine and MCPA applied at four growth stages on common waterplantain control and stand, and wild rice yield - Grand Rapids - 1981.

Common waterplantain growth stage	Herbicide	Rate	Common waterplantain Control	Common waterplantain Stand	Wild rice Yield	Wild rice Yield for each growth stage
		lb/A a.i.	%	Plants/ft^2	------lb/A*	---------
2 aerial leaf	2,4-D	1/4	13	0.6	560	
		1/2	24	0.5	529	
	MCPA	1/4	20	0.5	498	
		1/2	69	0.3	852	609
6 aerial leaf	2,4-D	1/4	9	0.6	412	
		1/2	26	0.5	598	
	MCPA	1/4	23	0.4	608	
		1/2	57	0.4	633	563
Scape elongation	2,4-D	1/4	32	0.5	465	
		1/2	58	0.5	632	
	MCPA	1/4	58	0.4	547	
		1/2	84	0.2	559	551
Early flowering	2,4-D	1/4	18	0.6	492	
		1/2	33	0.5	343	
	MCPA	1/4	10	0.6	345	
		1/2	38	0.5	218	349
Weed free			100	-	684	
Weedy check			0	0.6	345	
LSD .05			25	0.4	247	123

* 40% moisture

Table 3. The influence of two rates of 2,4-D amine and MCPA applied at four growth stages on common waterplantain control and stand, and wild rice yield - Aitkin - 1981.

Common waterplantain growth stage	Herbicide	Rate	Common waterplantain Control	Common waterplantain Stand	Wild rice Yield	Wild rice Yield for each growth stage
		/A a.i.	%	Plants/ft^2	----- lb/A*	---------
2 aerial leaf	2,4-D amine	1/4	8	2.7	156	
		1/2	34	0.9	395	
	MCPA	1/4	8	1.3	364	
		1/2	62	1.5	331	312
6 aerial leaf	2,4-D amine	1/4	10	2.2	268	
		1/2	15	1.5	215	
	MCPA	1/4	10	1.7	248	
		1/2	22	1.3	268	250
Scape elongation	2,4-D amine	1/4	28	1.9	160	
		1/2	88	0.7	256	
	MCPA	1/4	80	1.4	149	
		1/2	92	0.7	187	189
Early flowering	2,4-D amine	1/4	43	1.1	192	
		1/2	95	0.3	204	
	MCPA	1/4	28	1.6	155	
		1/2	88	0.4	168	180
Hand-weeded check			100	0	312	
Weedy check			0	2.7	152	
LSD .05			24	1.0	141	71

* 40% moisture

Common waterplantain control was significantly influenced by growth stage, herbicide, and rate at both Grand Rapids and Aitkin similar to common waterplantain grown alone. Comparable treatments, however, generally resulted in greater control of common waterplantain; possibly due to the added influence of wild rice interference.

At Grand Rapids the best control was achieved with MCPA at 1/2 lb/A a.i. applied at the scape elongation stage (when the flowerstalk first was visible under the water). Moreover, the number of plants were reduced by 33% with this treatment. Wild rice yield, however, was favored by early applications. The best yield was obtained with MCPA at 1/2 lb/A a.i. at the 2 aerial leaf stage. Applications of herbicide at the scape elongation stage or later were no better than the weedy check in this experiment for wild rice yield.

At Aitkin the same general results were obtained. Again by delaying herbicide applications until the scape elongation stage, greater waterplantain control is achieved. However, even though common waterplantain control is poor, wild rice yield is favored by early applications due to the reduction in competition of common waterplantain. Furthermore, the more mature the wild rice the more sensitive it becomes to these herbicides.

Table 4 summarizes a two year experiment on the effect of applying onto wild rice 2,4-D amine and MCPA at different growth stages. The floating leaf stage occurred on the average during the first week of June. These data indicate that wild rice is relatively tolerant during the floating leaf and first aerial leaf stages. Injury is evident at later application dates. Moreover, there was a significant yield reduction at both Grand Rapids and St. Paul with MCPA at 1/2 lb/A a.i. applied during the boot stage. These data suggest that in order to obtain maximum tolerance to wild rice and in order to avoid yield losses due to common waterplantain competition, phenoxy type herbicides should be applied as early as possible in the spring after sufficient leaf area of common waterplantain is above the water's surface. MCPA appears to do a much better job than 2,4-D on controlling waterplantain, but wild rice is also somewhat more sensitive to it. Further work with higher rates of both 2,4-D and MCPA at early growth stages needs to be conducted.

Table 4. Wild rice injury and yield as influenced by 2,4-D amine and MCPA applied at four growth stages - Grand Rapids and St. Paul (average of 2 years) - 1980 and 1981.

Growth stage	Herbicide	Rate	Grand Rapids Injury	Grand Rapids Yield	St. Paul Injury	St. Paul Yield
		lb/A a.i.	%	lb/A*	%	lb/A*
Floating leaf	2,4-D amine	1/4	0	730	0	1746
		1/2	0	691	2	1600
	MCPA	1/4	0	773	0	1623
		1/2	0	687	0	1882
First aerial leaf	2,4-D amine	1/4	0	664	0	1461
		1/2	4	664	0	1108
	MCPA	1/4	0	653	0	1475
		1/2	1	690	0	1439
Mid-tillering	2,4-D amine	1/4	4	678	6	1524
		1/2	6	687	8	1451
	MCPA	1/4	0	711	9	1112
		1/2	10	623	18	1304
Boot	2,4-D amine	1/4	9	666	8	1112
		1/2	20	714	28	1310
	MCPA	1/4	8	714	23	1116
		1/2	30	571	36	922
Untreated check				733		1537
LSD .05			8	123	7	487

* 40% moisture

Varietal response to 2,4- D amine was again investigated in 1981 at Grand Rapids. The varieties Johnson, Netum and K2 were treated with 1/4, 1/2 and 3/4 lb/A a.i. when in the early tillering, late tillering and early flowering stages of growth. Table 5 presents grain yield and moisture for the 3 varieties as influenced by rate and time of application of 2,4-D amine.

Table 5. Yield response of 3 varieties to 3 rates of 2,4-D amine applied at 3 growth stages - Grand Rapids - 1981.

Growth stage	Rate of 2,4-D amine		Variety					
			Johnson	K2	Netum	Johnson	K2	Netum
	lb/A a.i.		---- Grain yield, lb/A*---			----- % Grain moisture ---		
Early tillering	1/4		384	720	708	36	37	43
	1/2		432	840	960	38	36	41
	3/4		283	857	712	36	35	41
		Ave.	366	806	793	37	36	42
Late tillering	1/4		295	908	552	35	35	53
	1/2		408	828	480	35	35	51
	3/4		257	900	528	33	35	43
		Ave.	320	879	520	34	35	49
Early flowering	1/4		425	868	712	36	37	42
	1/2		312	724	720	40	34	41
	3/4		389	920	740	41	35	48
		Ave.	375	837	724	39	35	44
Control	0		256	795	615	41	37	45

* 40% moisture; yields not statistically different.

As was true for the two previous years, the varieties did not react differently to 2,4-D amine. No significant interaction for varieties and rate of 2,4-D amine was obtained. The growth stage at which 2,4-D amine is applied to wild rice is more critical than the variety. Even though the yields were not lower when 2,4-D amine was applied during early flowering, the chemical caused wild rice to lodge especially at the 3/4 lb/A a.i. rate. The recommended application time for 2,4-D amine is during or just before the tillering stage of growth and only at 1/4 lb/A a.i.

Often the degree of weed control obtained by chemicals is influenced by application time during the day. Thus, 2,4-D amine was applied at 1/4, 1/2 and 3/4 lb/A a.i. to wild rice and common waterplantain at 7 a.m., 1 p.m. and 8 p.m. on June 30 at Grand Rapids. The day was sunny with a high temperature of 78°F. Common waterplantain from rootstocks was beginning to flower while wild rice was tillering. Visual injury ratings and dry weights (grain for wild rice and shoots for waterplantain) were obtained for both species. There was no difference in response of either common waterplantain or wild rice to the 3 rates of 2,4-D amine whether applied in the morning, early afternoon or evening.

MCPA has shown some promise during the last 3 years for better control of common waterplantain than 2,4-D amine. The chemical was applied by airplane at 1/4 lb/A a.i. to a grower's field near Aitkin. The treated strip was 40 by 300 ft. Three paired plots (treated and untreated) were harvested with a combine. Each plot was 18 x 80 ft in size. The treated plots averaged 377 lb/A grain (40% moisture) while the untreated yielded 114 lb/A grain. The plots were combined close to the ground so all common waterplantain plants were harvested in addition to the wild rice. The treated plots had 420 lb/A common waterplantain seed while the untreated plots had 1434 lb/A. Further work will be done with early aerial applications of MCPA.

Further work was done with the rope-wick applicator as a means of applying MCPA to common waterplantain leaves without contacting wild rice. One gallon of MCPA (4 lb/gal a.i.) was mixed with one gallon of water. This solution was put into a 5 ft hand held rope-wick applicator. MCPA was applied onto 5 x 20 ft strips at 2 dates to common waterplantain in a grower's field near Aitkin. A single and double application was made at each date. Table 6 shows the results.

Table 6. Common waterplantain control in wild rice with MCPA when applied with a rope-wick applicator - Aitkin - 1981.

Application		Wild rice		Common waterplantain			
Date	Number	Panicles	Yield	Control	Plants	Height	Dry wt
		$/ft^2$	lb/A*	%	$/ft^2$	cm	/plant(gm)
6/2	One direction	6.5	166	47	5.5	53	3.4
	Two directions	7.6	133	63	3.4	50	3.1
6/11	One direction	6.6	155	63	3.4	43	3.0
	Two directions	7.5	158	82	2.3	58	3.9
Control		4.8	140	0	7.0	79	5.3

* Grain at 40% moisture

The first application was made on June 2 when common waterplantain had 2 to 3 leaves above the water (3-6 inches) and wild rice had only a few plants with aerial leaves. The second application was made on June 11 when common waterplantain had 4 to 5 leaves above the water and 20% of the wild rice plants had aerial leaves. At each date, all plots, except controls, were treated once. Half of the plots received a second application in the opposite direction from the first one. The best control (82%) of common waterplantain was obtained with two applications on the second date when 4 to 5 common waterplantain leaves were above the water. The use of a rope-wick type of applicator may be an effective way to control weeds in wild rice that emerge earlier than wild rice from the water. We are in the process of obtaining a use clearance for MCPA to use in rope-wick applicators.

Water Management and Weed Control

A study was conducted in large fiberglass boxes at St. Paul to determine the influence of fall flooding and burial depth on common waterplantain rootstock survival. Table 7 summarizes the results from this experiment. In this study, no common waterplantain rootstocks were viable in the spring if they were flooded in the fall. This could be due to a depletion of oxygen necessary for survival, similar to ice injury in alfalfa. Survival of common waterplantain rootstocks in the spring flooded treatment was greatest in the 3 and 6 inch depths. Survival of rootstocks on the surface and at 12 inches was less than 13%. These data suggest that fall flooding may significantly reduce the viability of common waterplantain rootstocks in the spring. However, this work is only preliminary, and further work is being done to substantiate the results.

Table 7. Common waterplantain survival as influenced by depth of burial and time of flooding of rootstocks - St. Paul - 1981.

Depth in soil	Spring flooded	Fall flooded
In.	% survival	
0	13	0
3	66	0
6	54	0
12	7	0
LSD .05 = 25%		

We continued our work with the influence of water depth on common waterplantain growth. Table 8 is a summary of the data collected at Grand Rapids in 1981. Seed weight and dry weight of common waterplantain for both seedling and perennial common waterplantain decreased with increased water depth. Plant height increased with water depth for common waterplantain grown from rootstocks, but plant height of common waterplantain seedlings was not influenced by water depth.

Wild rice yield was optimum at water depths between 3 and 11 inches, when wild rice was grown alone or with common waterplantain at a density of $1/ft^2$ (Table 9). Percent yield reductions, however, due to common waterplantain competition were greater at these depths, possibly indicating that water depth which favors wild rice growth also favors common waterplantain growth and competitiveness.

Table 8. The influence of water depth on growth of common waterplantain grown from seeds and rootstocks - Grand Rapids - 1981.*

Water depth	Established from rootstocks Dry wt	Seed wt	Plant ht	Established from seeds Dry wt	Seed wt	Plant ht
in	gm/plot	gm/plot	in	gm/plot	gm/plot	in
0	68.2	27.4	39	15.5	6.6	34
3	61.2	30.9	45	10.1	3.7	37
7	50.6	16.9	45	8.2	1.9	35
11	47.0	9.3	48	5.6	0.5	33
19	43.7	12.3	55	3.2	0.0	33
Correlation coefficient(r)	-.92*	-.78*	.97*	-.94*	-.90*	-.6

*Significant at the 5% level

Table 9. The influence of water depth on wild rice yield when grown alone or with common waterplantain from rootstocks at a density of $1/ft^2$ - Grand Rapids - 1981.

Water depth	Wild rice yield alone	Wild rice yield with weeds	Yield reduction
in	lb/A*	lb/A*	%
0	256 c	171 b	33
3	698 a	309 a	56
7	688 a	235 ab	66
11	458 b	192 b	58
19	229 c	176 b	23

*Green weight basis.

PLANT POPULATION

Plant Population and Yield of Netum

Netum was seeded in the spring at 5, 15, 45, 90, 135 and 150 lb/A of wet seed at Grand Rapids. The seed was broadcast onto the soil surface and rotovated 1 inch deep into the soil. This experiment was similar to one conducted last year but with two higher seeding rates. Last year the highest seeding rate was 100 lb/A. Results of the 1981 trial are given in Table 10.

Table 10. Plant characteristics and yield of Netum as influenced by plant population - Grand Rapids - 1981.

Seeding rate	Plants	Plant height	Grain moisture at harvest	Grain weight at 40% moisture
lb/A	/ft^2	cm	%	lb/A
5	0.1	178	48	102
15	0.3	198	41	520
45	0.5	188	41	492
90	1.1	193	40	704
135	1.2	190	38	886
150	1.4	180	38	870
LSD .05	0.3	20	--	180

As last year, the yield continued to increase as seeding rate increased. This was also true for plant population. We had expected a higher plant population based on percent viable seed. Higher plant populations will have to be established before we can indicate what the optimum plant population is for Netum.

SIMULATED HAIL DAMAGE

Leaf Removal and Stem Breakage

A repeat of the 1980 simulated hail study was conducted at Grand Rapids. To simulate hail damage on wild rice, 33, 67 and 100% of each leaf blade was cut off with a scissors at 7 growth stages. The leaf tissue was removed at the floating leaf, aerial leaf, tillering, flowering, milk, soft dough and first dark kernel stages of growth. In addition, 33, 67 and 100% of the stems were broken below the panicle. The stems, however, were not completely broken off. Table 11 gives the data obtained at harvest from the various leaf removal and stem breakage treatments.

Table 11. Influence of removing 33, 67 and 100% of leaves on wild rice plants at 7 stages of growth plus 33, 67 and 100% of stems broken at last 4 stages of growth - Grand Rapids - 1981.

Growth stage	Leaf removal	Plant number	Stem number	Plant height	Panicle number	Straw dry weight	Grain weight	Grain yield reduction from no leaf removal 1981	1980	Ave.
	%	$/ft^2$	$/ft^2$	cm	/plant	lb/A	lb/A*	----------- %	-----------	
Floating leaf	33	2.2	10.2	159	4.6	2736	848	19	20	20
	67	2.1	9.3	169	4.4	2736	712	32	17	24
	100	2.2	7.0	152	3.2	2592	657	37	62	50
Aerial leaf	33	2.0	9.0	159	4.5	3312	752	29	17	23
	67	2.3	11.9	170	5.2	3312	888	15	3	9
	100	2.0	8.9	157	4.4	2304	497	52	9	30
Tillering	33	2.2	10.6	163	4.8	2976	872	17	3	10
	67	2.2	10.4	155	4.7	3072	783	25	0	12
	100	2.2	10.2	168	4.6	2640	648	38	41	40
Flowering	33	2.2	11.0	155	5.0	2784	800	23	0	12
	67	1.9	9.1	159	4.8	2688	897	14	24	19
	100	1.8	6.4	127	3.6	1536	272	74	80	77
Milk	33	2.0	8.7	159	4.4	2976	640	39	3	21
	67	1.8	12.5	150	6.9	2736	672	36	32	34
	100	1.8	8.0	124	4.4	1872	328	69	43	56
Soft dough	33	2.1	9.0	159	4.3	3216	880	16	--	16
	67	2.6	10.8	152	4.2	3408	912	13	--	13
	100	2.0	8.8	131	4.4	2400	440	58	--	58
First dark	33	2.2	10.2	152	4.6	3216	808	23	--	23
	67	2.0	7.5	165	3.8	2448	657	37	--	37
	100	2.0	9.8	117	4.9	2448	583	44	--	44
Control	0	2.0	10.8	158	5.4	3579	1045			
LSD .05		0.5	2.4	29	1.2	678	256	--	--	--

* 40% moisture

Removing a portion or all of the leaves during the floating leaf stage again resulted in considerable yield losses. For the two years, the loss was 50% when all of the floating leaves were removed.(last column in Table 11). The floating leaves apparently are very important for early plant development. The average yield loss for the 2 years from removing the leaves during the aerial and tillering growth stages was less than when they were removed during the floating leaf stage. Yield losses averaged over the two years were greatest when 100% of the leaves were removed plus 100% of the stems broken during flowering. Losses declined when this treatment was made at later dates. As with other small grains, leaf removal during flowering or grain filling in wild rice results in yield losses. Yield losses are small in other small grains when leaves are removed earlier. However, yield losses in wild rice can be considerable if leaves are removed early, especially during the floating leaf growth stage.

TIME OF HARVEST

Netum Date of Harvest

The variety Netum was harvested for a second year over a period of 20 days to ascertain when to harvest this variety for maximum yield. The results from the 1981 trial are given in table 12.

Table 12. Netum yield and grain moisture as influenced by harvest date - Grand Rapids - 1981.

Harvest date	Grain yield	Grain moisture at harvest
	lb/A*	%
8-25	1075	45.1
8-28	1290	45.5
9-1	1329	47.7
9-4	1651	36.5
9-9	1309	33.9
9-14	849	29.7
LSD .05	473	--

* 40% moisture

Last year maximum yield was obtained when grain moisture was 41%, while in 1981 maximum yield was obtained when the grain had 36.5% moisture. Trials with other varieties indicated maximum yield when the grain has about 39% moisture. Thus, it appears that Netum produces maximum yield at similar grain moisture as the other varieties.

Grain Moisture at Harvest and Recovery Percent

About one pound of grain was hand harvested from 17 fields that were being harvested by growers. The moisture percent and percent recovery based on initial green weight was obtained for all grain samples. The moisture percent was obtained by the oven method and percent recovery by dehulling the grain with a small laboratory dehuller constructed by John Strait. Table 13 presents the values obtained for the grain samples.

Table 13. Moisture and recovery percent of hand harvested grain samples from 17 fields during harvest - Aitkin and Clearwater Counties - 1981.

Sample number	Moisture percent	Recovery percent*	Sample number	Moisture percent	Recovery percent*
1	37.6	43.3	10	31.2	46.2
2	37.4	41.7	11	33.1	39.0
3	37.1	42.0	12	37.2	36.4
4	42.8	33.1	13	34.2	41.1
5	44.6	30.3	14	34.7	39.5
6	39.4	36.5	15	34.6	39.1
7	38.5	34.9	16	33.5	34.8
8	39.9	25.7	17	32.8	39.9
9	41.8	37.5			

Correlation coefficient (r) = -.631

* Dried dehulled grain weight ÷ wet grain weight x 100

The moisture percent ranged from 31.2 to 44.6 while percent recovery ranged from 25.7 to 46.2. The correlation coefficient (r) was calculated for grain moisture percent and recovery percent. The correlation coefficient is a measure of the degree to which grain moisture and recovery percent vary together. If the correlation value would be 1.00, then one would vary exactly as the other. In this case if the moisture percent increased, the percent recovery would decrease proportionately. The correlation coefficient of -.631 is statistically significant (5% level) which means that as grain moisture decreased the percent recovery increased. The value, however, was not as great as expected probably because some fields were heavily diseased.

Another set of data on recovery and moisture was obtained by Dr. Stucker from his breeding plots. Table 14 shows the actual values and the correlation of moisture and recovery percent.

Table 14. Moisture and recovery percent of grain from advanced yield trials - 1981.*

	Excelsior			Grand Rapids	
Sample	Moisture percent	Recovery** percent	Sample	Moisture percent	Recovery percent
1	34.6***	49.4***	1	41.5	33.2
2	31.8	49.7	2	36.4	38.2
3	32.7	51.8	3	42.4	35.5
4	33.5	50.3	4	43.1	33.6
5	32.4	52.0	5	38.6	38.0
6	31.7	53.4	6	39.3	41.0
7	32.0	52.0	7	36.9	41.9
8	31.6	46.4	8	32.8	44.1
9	32.9	50.8	9	36.2	38.9
Correlation coefficient (r) = -.904					

* Data from R.E. Stucker

** Dried dehulled grain weight ÷ wet grain weight x 100

*** Each value is an average of 6 replications

The correlation coefficient was much higher (-.904) with the more uniform plots and more samples involved than in the previous study. It appears that grain moisture could be used as a good indicator of percent recovery (i.e. when to begin harvesting) by growers if a rapid and relatively accurate moisture meter would be available for wild rice. Ordinary grain moisture meters will not accurately test grain with high moisture. Our limited testing last year indicated forage moisture testers might be usable for this purpose. One which worked well was the Koster Crop Tester. It takes about 25 minutes to test the grain but might be suitable for wild rice growers.

WILD RICE PLANT DEVELOPMENT

Temperature and Daylength Response

The growth chamber experiments which were started 2 years ago to investigate the response of wild rice to temperature and daylength were completed in 1981. The Johnson nonshattering and Canadian shattering varieties were grown with 9 hours of full light and 9 hours of full plus 6 hours of low light. These two light regimes simulated a 9 hr and a 15 hr daylength. In addition to the two daylengths, the varieties were also grown at two temperatures at each daylength. The two temperatures were: 1) 19°C during the day (14 hr) and 16° C during the night period (10 hr) and 2) 22° C during the day and 16°C during the night period. The plant measurements made were days to floral initiation, days to flowering, plant height, tiller number, floret number and dry weight per plant. Figures 1 through 6 give the average values for the two varieties since both varieties responded the same to the different temperatures and daylengths. The two temperature values at the bottom of the graphs are the average day/night temperature for the two temperature regimes.

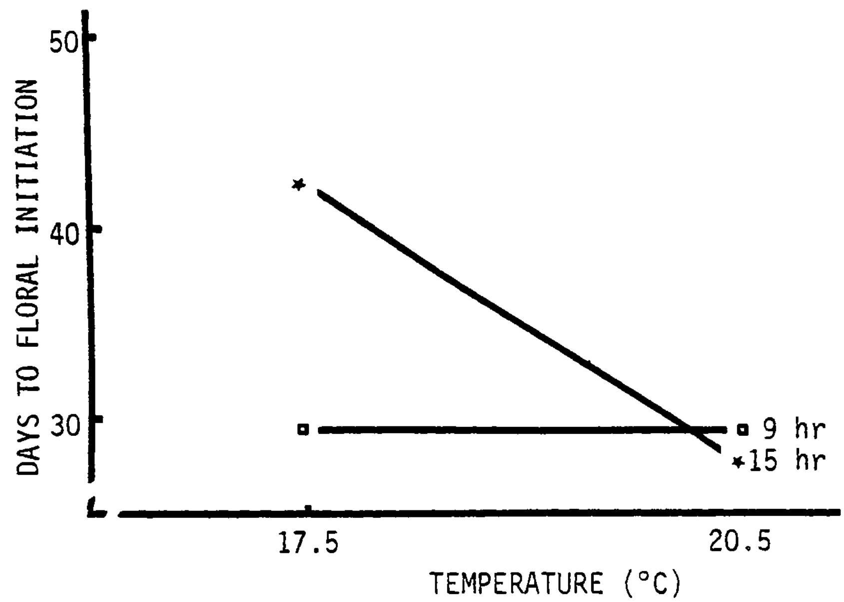

Figure 1. The number of days for flower initiation for wild rice grown at each daylength and temperature.

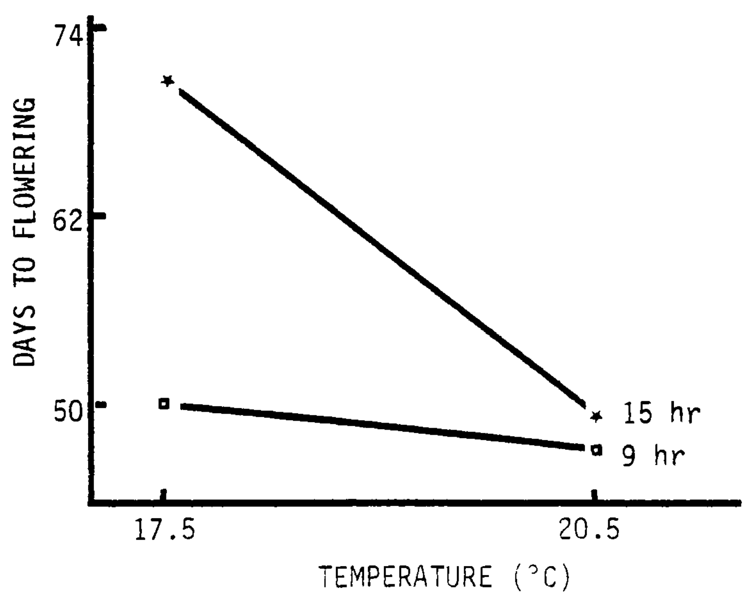

Figure 2. The number of days to flowering for wild rice grown at each daylength and temperature.

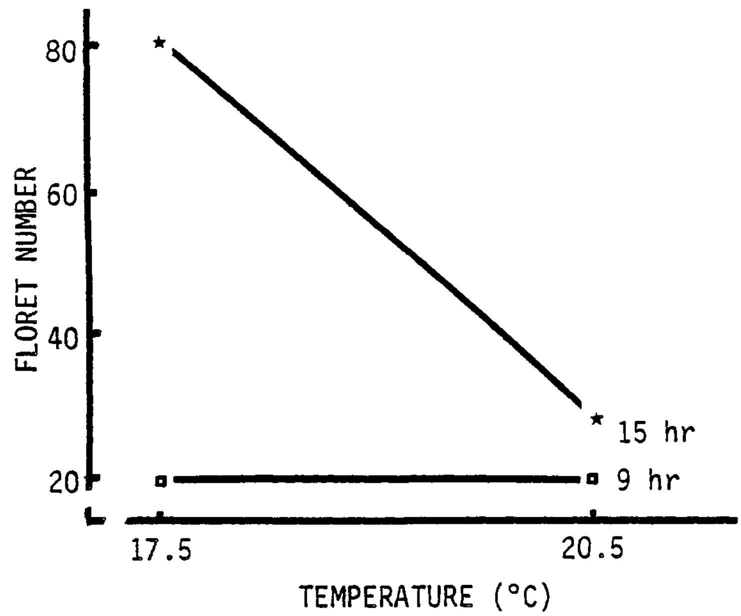

Figure 3. The number of female florets per panicle for wild rice grown at each daylength and temperature.

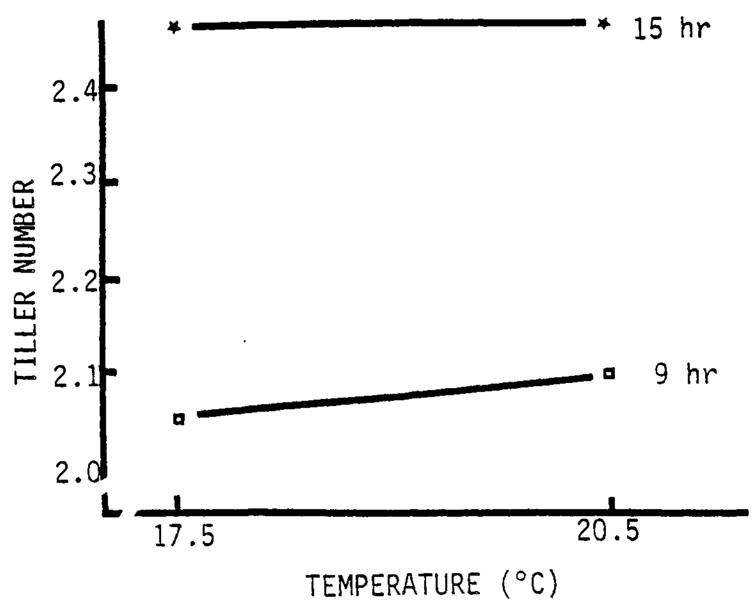

Figure 4. The number of tillers per plant for wild rice grown at each daylength and temperature.

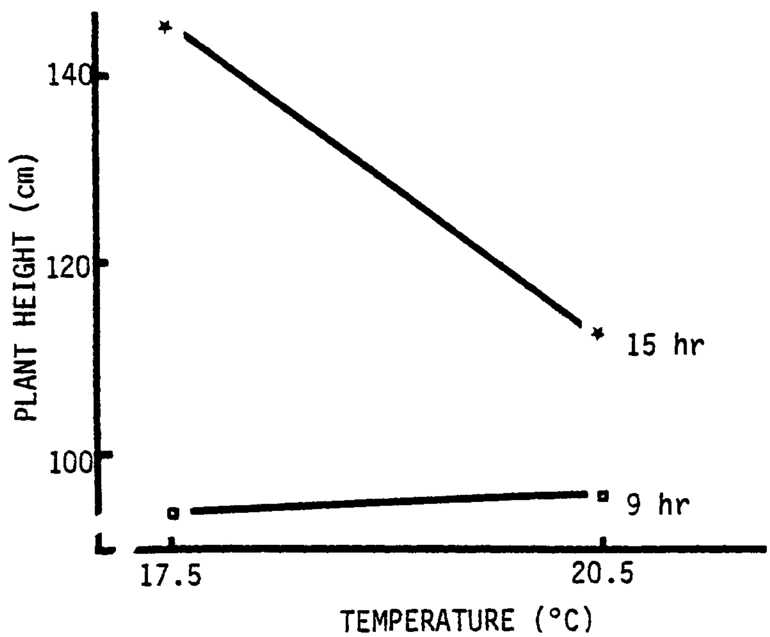

Figure 5. Wild rice plant height when plants were grown at four temperature/daylength regimes.

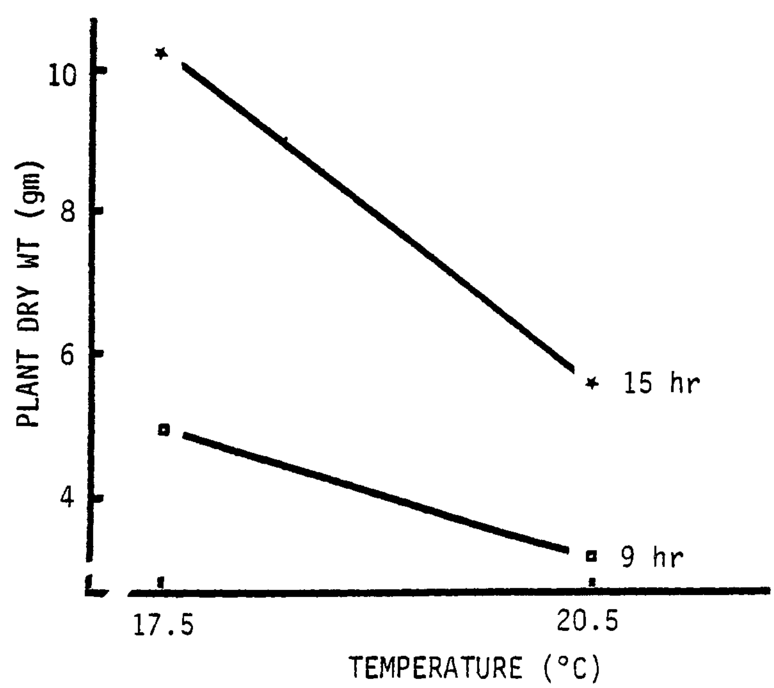

Figure 6. Wild rice plant dry weight when plants were grown at four temperature/daylength regimes.

The influence of temperature on flower initiation (formation of small bulges on growing point) can readily be seen, especially at the 15 hour daylength (Figure 1). It took 14 days longer for floral initiation when plants were grown in the cool (17.5° C) than in the warm (20.5° C) temperature. However, there was no difference in temperature response when the plants were grown with 9 hours of daylength. The flowering response of wild rice to temperature and daylength was similar to the days to flower initiation (Figure 2). It took 17 days longer for the plants to flower in the cool compared to the warm temperature when they were grown with 15 hours of light. There was very little temperature response when the plants were grown with 9 hours of light. The number of female florets (grains) per panicle was considerably greater at the cool temperature compared to the warm temperature when the plants were grown with 15 hours of light (Figure 3). There was no response to temperature when they were grown with 9 hours of light.

The numbers of tillers per plant did not change with temperature at both daylengths (Figure 4). The tiller number, however, was greater when the plants were grown with 15 hours compared to 9 hours of light. Wild rice plant height was much greater at the cool than warm temperature with 15 hours of light but this was not true with 9 hours of light (Figure 5). Plant dry weight was greater at the cool compared to the warm temperature when the plants were grown with either 9 or 15 hours of light (Figure 6).

In summary, wild rice plants grown in the cool temperature were taller and had more tillers and female florets per panicle than those grown in the warm temperature. Plants in the warm temperature grew more rapidly than in the cool temperature. Plants with the 9 hours of light flowered earlier, were shorter and had fewer tillers per plant and fewer female florets per panicle than with 15 hours of light. Plant response to temperature was not as great when grown with 9 hours compared to 15 hours of light. Temperature changes in the 9 hours of light did not influence flowering date, but plants flowered earlier in the warm compared to the cool temperature with 15 hours of light. With the help of Dr. George Snyder, University of Florida, Belle Glade, Florida and Dr. Frank Wooding, University of Alaska, Fairbanks, Alaska, the variety Netum was planted in Florida and Alaska to compare plant growth in these locations to growth in Minnesota. Table 15 gives the number of days and growing degree days needed for the variety Netum to reach the tillering, flowering and mature stages of growth at the three locations.

Table 15. Plant development of Netum when planted at 3 divergent locations.

Growth stage	Location* Belle Glade, Florida Days	GDD**	Grand Rapids, Minn. Days	GDD	Fairbanks, Alaska Days	GDD
Tillering	--	--	45	850	57	966
Flowering	43	1395	83	1834	98	1937
Mature	64	1978	115	2680	135	2436

* Planting date: FL, 4/17; MN, 5/1; Alsk, 5/9
Daylength on June 15: FL, 14 hr; MN, 15-3/4 hr; Alsk, 21-1/2 hr

** Growing degree days calculated using 40° F as base temperature

In Florida the plants had very few tillers, thus no tillering date could be obtained. However, in Alaska the plants took 12 days longer to tiller than in Minnesota. Flowering occurred in 43 days in Florida, 83 in Minnesota and 98 in Alaska. The plants matured in 64 days in Florida but took 135 days to mature in Alaska and even then they were not completely mature since the experiment was terminated because of freezing temperatures. The number of growing degree days it took in Florida to reach each stage of growth was less than in Minnesota or Alaska, thus the shorter daylength in Florida, probably enhanced growth in addition to the warmer temperatures. We have concluded from the growth chamber work and the plantings in Florida and Alaska that warm temperatures will accelerate plant development and the acceleration is greatest when in combination with short daylengths.

ACKNOWLEDGEMENTS

We wish to thank Henry Schumer, plot supervisor, at Grand Rapids for his continued, cheerful support of our research. Without his daily supervision the work at Grand Rapids would not have been possible. The help of Joe Rust, Jim Boedicker, Dave Rabas and Jana Campbell at Grand Rapids was also appreciated. The use of John Strait's dehulling equipment was very useful and appreciated. Several growers, Kelly Petroski, Franklin and Harold Kosbau, Art Hedstrum, Hubert Jacobson, Ray Skoe and George Landreth, provided land or seed for our research. Their help was greatly appreciated.

WILD RICE BREEDING - 1981

R. E. Stucker, G. L. Linkert, L. A. Everett,
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Agronomy and Plant Genetics

I. Progress report on K2E(2)

Seed increase and release of new varieties require approval of the Minnesota Crop Variety Review Committee. K2E(2) was developed by 2 cycles of selection for early flowering in the variety K2. It continues to look promising. Below is a copy of our report to the committee seeking permission to increase the seed supply of K2E(2). Permission was granted based on the evidence to this point.

Report to Minnesota Crop Variety Review Committee
November 5, 1981

SUBJECT: Progress report on wild rice strain K2E(2) and request for continued increase. K2E(2) was derived from the variety K2 by two cycles of mass selection for early flowering.

A. Results of 1981 experiments at Grand Rapids and Excelsior.

Conclusion: K2E(2) is significantly earlier than the parent variety K2 and equal in maturity to Netum,the present early variety. There is no evidence to suggest that K2E(2) will be lower yielding than K2 because of selection for early flowering. Thus, we believe that K2E(2) will be equal to Netum in maturity and equal to K2 in yield.

Discussion: In 1981 K2E(2) was evaluated in advanced yield tests conducted in six replicates at Grand Rapids and at Excelsior. Flowering date means are shown in Table 1 as days after July 1. Results at both locations were very similar. K2E(2) flowered about 1 week earlier than the parent variety and 1 day earlier than Netum,the present early variety available to growers.

To assess relative maturity at harvest, Netum, K2, and K2E(2) were harvested on a common day at Grand Rapids (Table 2). K2E(2) was significantly lower than K2 in moisture and significantly higher than K2 in percent recovery of dry grain. As would be expected if K2 were harvested before it was mature, K2E(2) yielded significantly more dry grain than K2. K2E(2) yielded more than Netum but the difference was not significant. In both percent moisture and % recovery, K2E(2) was in the right direction for being at least equal to Netum in maturity and possibly slightly earlier.

At Excelsior, plots were harvested when they were mature. Thus, indicators of relative maturity are date of harvest, percent moisture at harvest and percent recovery. The average date of harvest for K2E(2) was 7 days earlier than for K2 and 5 days earlier than Netum. Percent moisture means indicated that K2E(2) was dryer than K2 and percent recovery for K2E(2) was better than for K2. The evidence suggests that K2E(2) was significantly earlier than K2. The lower percent moisture of Netum indicates that we probably harvested Netum somewhat later than the stage of maturity of K2E(2). K2E(2) still had a better percent recovery. Excelsior data are given in Table 3.

The yield comparison is valid only at Excelsior. There is no evidence that K2E(2) will be lower yielding than K2 because of selection for early flowering. Both K2 and K2E(2) were better yielding than Netum but the large standard error for yield prevents us from saying K2E(2) is significantly better than Netum.

Our objective in the selection experiment was to develop a version of K2 which was as early as Netum but which did not yield significantly less than K2 itself. Evidence to this point indicates that we have accomplished the objective.

Table 1. Maturity comparisons of K2E(2) versus check varieties. 1981.

	Flowering Date*		
Entry	Excelsior	Grand Rapids	Combined
Netum	14	8	11.0
K2	19	14	16.5
K2E(2)	13	7	10.0
M3	21	19	20.0

* Days after July 1.

Table 2. Maturity comparisons of K2E(2) versus K2 and Netum--yield at a common harvest date.* Grand Rapids, 1981.

Entry	Grain** dry weight	Percent Moisture	Recovery percent
Netum	577	36.4	38.2
K2	514	41.5	33.5
K2E(2)	648	36.2	38.9
LSD (.05)	130	1.7	3.1

* Harvested August 20, 1981.

**Pounds per acre of dehulled grain.

Table 3. Yield comparison of K2E(2) versus check varieties at maturity. Exclesior, 1981.

Entry	Harvest* date	Grain** dry weight	Moisture percent	Recovery percent
Netum	51	581	31.8	49.7
K2	53	682	34.6	49.4
K2E(2)	46	682	32.9	50.8
M3	57	854	33.5	50.3
LSD (.05)	2	192	1.7	2.8

* Days after July 1.

** Pounds per acre of dehulled grain.

B. Plans for 1982

Testing

K2E(2) has been fall planted in replicated tests at Gully, Waskish, Grand Rapids and Rosemount. A spring planting is planned for Excelsior. Data on flowering date, percent moisture at harvest, percent recovery of dry grain and yield of dry grain will be collected. If all plantings are usable, 30 replicates will be available for evaluating K2E(2) in several areas over the range of wild rice paddy production in Minnesota.

"End of Report"

Plans for Increase

We plan to plant approximately 1 acre of isolated increase in 1982. The resulting seed will be transferred to the Minnesota Crop Improvement Association for contract production of the potential variety. The increase field(s) would then be fall planted, 1982 to produce foundation seed.

In fall 1983, the harvested seed would probably be available for sale to growers of certified seed. Fall planting and the seed storage problem complicate normal release procedures. The next major decision is dependent on favorable performance of K2E(2) in the 1982 tests. If K2E(2) continues to show earliness without loss in yield compared to K2, MCIA will continue with the contract increase, fall 1982.

Tests grown in 1983 will have to be summarized immediately. Probably a special session of the Crop Variety Review Committee will be necessary in order to make a release decision in time for fall planting in 1983, since the normal November meeting will be after fall planting time.

II. Additional facilities

We submitted a grant proposal to the Minnesota Crop Improvement Association for money to build additional isolation paddies in 1981. Our application was approved. A brief report on the proposal was submitted to MCIA. It is reprinted below:

Report on Grant from MCIA

Title: Germplasm Maintenance and Breeder Seed Increase for Foundation Seed Production of Wild Rice.

Investigator: R. E. Stucker
Agronomy and Plant Genetics

Amount Granted: $4,100

Purpose: The primary purpose of the grant proposal was to construct 2 wild rice paddies which could be used to increase Breeder Seed or maintain small breeding populations in isolation. The two paddies were to be constructed at the Rosemount Experiment Station. Actual construction costs were considerably less than the estimates I received because a different contractor built the Rosemount paddies. Thus, I had the Grand Rapids Experiment Station construct one additional paddy in 1981 and allotted monies to build a companion paddy in 1982. The total costs of construction exceeded the grant amount by some $800. The difference was covered by project funds. Paddies, 100' X 40', were netted and are functional except for the fourth paddy which will be built, spring '82. Thus, the project will have 3 paddies available for use annually.

Accomplishments to Date: One paddy at Rosemount was used to increase Breeder Seed of K2E(2). We harvested approximately 35 pounds of green seed which will be used to plant one acre of Foundation Seed increase in the spring of 1982. The second paddy at Rosemount was used to maintain a population M3E(2). Approximately 10 pounds of green seed was obtained. Problems with our irrigation well resulted in variable water levels in this paddy and lower yields resulted.

The Grand Rapids paddy was used to grow a promising population, M3 X Netum, which has also been selected for earliness. In this population we did within and among family selection for plant type and panicle type. Approximately 10 pounds of the selected seed were obtained.

Summary: The addition of 3 small isolation paddies has added immensely to the flexibility of the breeding project. We expect to gain considerably in breeding progress through the use of the new paddies in the years to come. Also, we can use our larger isolation paddies to grow bigger increases when necessary. The alternative would have been to use grower locations where our production control would likely be restricted.

III. Breeding for reduced shattering

In 1981 Les Everett completed his Ph.D. thesis experiment, an evaluation of the effectiveness of two selection methods in increasing strength of seed retention at maturity. Both selection and evaluation of progress from selection were made on the basis of force required by a spring loaded meter to pull a seed from a panicle when approximately 40-50% of the seeds on the panicle had darkened in color and were firm. The test population was the variety Netum.

Two cycles of mass selection for seed retention were completed in the greenhouse in the fall of 1979 and 1980. In the first cycle 750 plants were evaluated for average tensile strength retention based on 10 seeds sampled from the main stem. Seeds from the best 75 plants were planted for intermating. The resulting seed was planted in 1980 and the best 50 plants out of 500 were selected on the basis of tensile strength. The bulked seed from the 50 selected plants formed the second cycle of selection [Net(M2)]. This was evaluated in the field in 1981.

One cycle of unreplicated half sib selection was performed in the field in 1980. Seed from 226 random open pollinated plants was planted, the seed from an individual plant in a single row. Selection was based on average tensile strength of 5 seeds per panicle on each of 5 plants in a row. The best 10% of the rows within each of 5 field blocks were identified and remnant seed of the selected families was grown and open pollinated in the greenhouse, fall 1980. Seed from this intermating was bulked to form the half sib selected population [Net(HS1)].

In 1981 we tested five populations: Netum, Netum Mass Cycle 2 [Net(M2)], Netum Half Sib [Net(HS1)], K2, and Experimental 3. Experimental 3 has the same background as Netum but had been further selected for plant type, maturity, and seed retention. The five entries were planted at Excelsior and Grand Rapids, 15 replicates in 6 foot long two-row plots. The evaluation criterion was tensile strength of 5 seeds per main stem (or most mature tiller) on each of 10 plants per plot. Pest damage reduced the number of plants per plot at Excelsior in some reps. All measurements were made by Les Everett at Excelsior and Jana Campbell at Grand Rapids.

The results are summarized as follows:

Mean Tensile Strength (grams of pull)

	Population				
Location	Netum	Net (HS1)	Net (M2)	K2	Exptl 3
Excelsior	84	105	141*	81	142*
Grand Rapids	120	131	164*	132	182*

* Significantly greater than Netum (.05 LSD)

There was a large amount of variability in the data on a seed within plant, plant within plot, and plot to plot basis. Statistically significant separation of these means at the 5% probability level showed an increase in tensile strength after two cycles of mass selction, but not from one cycle of half sib selection. This result is encouraging because it would permit selection in the off season greenhouse on the basis of individual plant data, thus reducing field labor at a critical time. The fact that Experimental 3 had previously undergone mass selection for tensile strength (without subsequent evaluation) and was equal to Net (M2) is additional evidence of the effectiveness of this selection scheme. The results of this experiment suggest that K2 does not differ significantly from Netum in seed retention.

This experiment leaves open three issues: 1) Does selection for tensile strength cause a change in other characters, such as yield? 2) How well does a change in mean tensile strength correlate with reduced field losses? and 3) Is there a less time consuming method for selection than recording 5 observations per plant with a tensile force meter? It does show that genetic variability for seed retention exists in Netum and that we can change the mean seed retention by selection.

IV. Varietal comparisons for seed retention

The comparison of seed retention in non-shattering varieties was continued in 1981 as a part of Larry Boze's Masters thesis. The 1981 experiment evaluated fewer varieties than in 1980 so that more plants could be sampled from each variety. The varieties and populations evaluated were M3, K2, Netum,K2 early cycle 1 [K2E(1)], Dwarf and Experimental 3. K2E(1) resulted from one cycle of mass selection for earliness in K2 (See 1980 progress report) and Experimental 3 was derived from Netum background following additional selection for seed retention. Six replicates of each population were spring planted at Excelsior in 4-row plots measuring 4'x10', with 1 foot spacing between rows and a skip row between plots. Seed retention was measured with a tensile force meter. Five dark kernels were measured on each of 15 randomly selected plants in each plot, when approximately 50% of the kernels on a panicle were dark.

The results are shown as population means based on 15 plants and 5 kernels per plant, in each of the six replicates (Table 4). The 1980 results are included as a basis of comparison but we regard them to have greater sampling error than 1981 results. The difference among population means was significant. M3 had the lowest seed retention; Experimental 3 had the highest. The other populations were intermediate and not signficantly different from each other.

We regard this to be reasonable evidence that genetic differences do exist for seed retention among the populations tested. Mean tensile strengths for K2 and Netum were similar. Everett's independent measurements also showed them to be similar as did Jana Campbell's measurements. The difference between Everett's measurements and the other two can be attributed to experimental technique involving stage of sampling.

The 1980 measurements (Table 4) showed M3 to have the lowest seed retention among those varieties common to both years. Also, K2E(1), K2,Netum and Dwarf were not significantly different in mean seed retention in 1980 (as in 1981).

Heritability values are used to express the amount of genetic variance for a trait in percent of total variance. High heritability (70-100%) values suggest that progress from selection should be rapid. Low values (10-30%) indicate relatively low genetic variance for a trait. The 1981 estimates of heritability for seed retention (Table 4) are in the high range and are encouraging. Everett's progress from mass selection is supporting evidence that there is sufficient genetic variance for seed retention such that progress is attainable. For theoretical reasons, however, we must still be cautious in the interpretation of Boze's estimates of heritability.

The results of the two experiments on seed retention give us confidence that we can make genetic progress for shattering resistance. However, the progress is not likely to be rapid. We intend to initiate experiments to do whole-plant evaluation for seed shattering. With the able engineering of Dr. Cletus Schertz, we have a machine that we hope can be used to evaluate a large number of plants in a 2 or 3-day time span. If it works, I hope we can start a large scale selection program for increasing the shattering resistance in several populations. This is just not feasible with the tensile strength meter.

Table 4. Mean seed retention and heritability estimates of seed retention in six populations of wild rice (Excelsior, 1980 and 1981).

Population	Tensile strength 1980[1/]	Tensile Strength	Heritability(%)
M3	62[a]	83[a]	75
K2E(1)	134[b]	114[ab]	73
K2	144[b]	120[ab]	33
Netum	110[b]	126[ab]	74
Dwarf	128[b]	150[bc]	78
Experimental 3	---	187[c]	57
LSD (.05)[2/]	40	49	--

[1/] Expressed as grams of pull measured by a tensile force meter.

[2/] Differences among means followed by the same letter are not significantly different.

V. An evaluation of the Dwarf population

The population, Dwarf, is characterized by short stem length, very early maturity and large seed size. We also have reason to believe that its yield potential under common planting density and fertilization practices will be low. To obtain a better understanding of its yield potential, we evaluated it at Grand Rapids using 2 rates of nitrogen fertilization and three rates of planting. Netum and K2 were evaluated similarly as control populations. The experiment was fall planted in a randomized complete block design replicated 4 times. The varieties (Dwarf, K2, and Netum) were arranged in whole plots, the two nitrogen-rate treatments were applied in split-plots and the planting densities formed the split-split-plot treatment. Each split-split-plot consisted of 4 rows, 8 feet in length, spaced 1 foot apart with a skip-row between plots. We planted approximately 8, 16, and 24 sound kernels per linear foot of row to create the densities of planting. Nitrogen was applied at two rates, 15 pounds of actual N or 55 pounds actual N, in form of urea.

At maturity for each variety, we measured height and yield of the center two rows, and counted plant number and stem number. At the date of harvest, we obtained % recovery estimates for the nitrogen-variety combinations in each replicate (Northern Rice Lab). Recovery percentage was obtained for each plot of Netum and K2. Dry grain was dehulled in John Strait's laboratory. Recovery was computed as weight of clean grain in percent of green weight.

The dwarf population, as expected, was very short and early (Table 5). Dwarf was significantly lower in yield than either Netum or K2. K2 was somewhat higher in yield than Netum but the difference was not significant.

The effect of planting density on yield was highly significant (Table 6). All three populations responded similarly to increased density (Figure 1). We hoped that at the high density, Dwarf might be close to the yield levels of Netum or K2 at lower stand densities. The results (Table 6) indicate that Dwarf will not be a good producer unless it is planted at a very high rate. The number of stems per plot at the high rate of planting for Dwarf indicated good tillering potential but relatively lower yield per stem than Netum or K2. I suppose we should try planting Dwarf at an even higher rate to see if it will continue to increase in yield. Figure 1 illustrates a good linear response of yield to plant density for Dwarf. Netum and K2 appear to be reaching a plateau either in tillering and/or yield between the intermediate and high density.

All three varieties responded to nitrogen fertilization in this evaluation on mineral soils. This response occurred at each planting density for each variety except for the Dwarf population at the higher rate of planting (Table 7). At the higher rate of nitrogen (55 lb/A), both Netum and K2 showed reduced yield at density 3 compared to yield at density 2. A small experiment like this doesn't provide much basis for a sound conclusion. Nevertheless, I wonder if the higher rate of nitrogen provided good early growth and tillering, and at grain filling the plants did not have adequate nitrogen for completing the potential yield.

I would like to see someone plant about 2 to 5 acres of Dwarf at a high planting density. I think this will be the only way we can get an idea of its true potential. The extreme shortness (43 inches compared to 72 inches for Netum) and earliness could be quite an advantage to a grower who would like to spread his harvest work load and risk.

Table 5. Harvest date and variety means for stand, % recovery, yield and height in the Dwarf population experiment at Grand Rapids (Means of 4 replicates, 3 densities and two nitrogen levels.)

Variety	Stand (% survival)	Harvest date	% Recovery	Mean[1/] Yield	Height (in)
Dwarf	29	7/28	46.8	566	43
Netum	29	8/20	46.6	1160	72
K2	22	8/25	41.6	1206	77
LSD (.05)			1.4	87	

[1/] Yield of dehulled dry grain in pounds per acre.

Table 6. Effect of planting density on plants per plot, stems per plot, yield per acre and % recovery for Dwarf, Netum and K2 (Grand Rapids).

Variety	Density	Plants per plot	Stems per plot	Grain[3] yield	% recovery
Dwarf	1[1]	22[2]	140	336	-
	2	35	230	594	-
	3	50	294	768	-
Netum	1	22	156	888	44.6
	2	38	233	1272	47.5
	3	46	260	1320	47.8
K2	1	17	128	888	39.7
	2	29	199	1320	42.5
	3	33	220	1410	42.4
LSD (.05)--(for comparing densities within varieties)				150 lb/A	1.5%

1/ 8, 16, and 24 seeds per linear foot of row were planted for the three densities, respectively.

2/ Each tabular value is the mean of 4 replicates and 2 nitrogen levels.

3/ Yield of dehulled grain in pounds per acre.

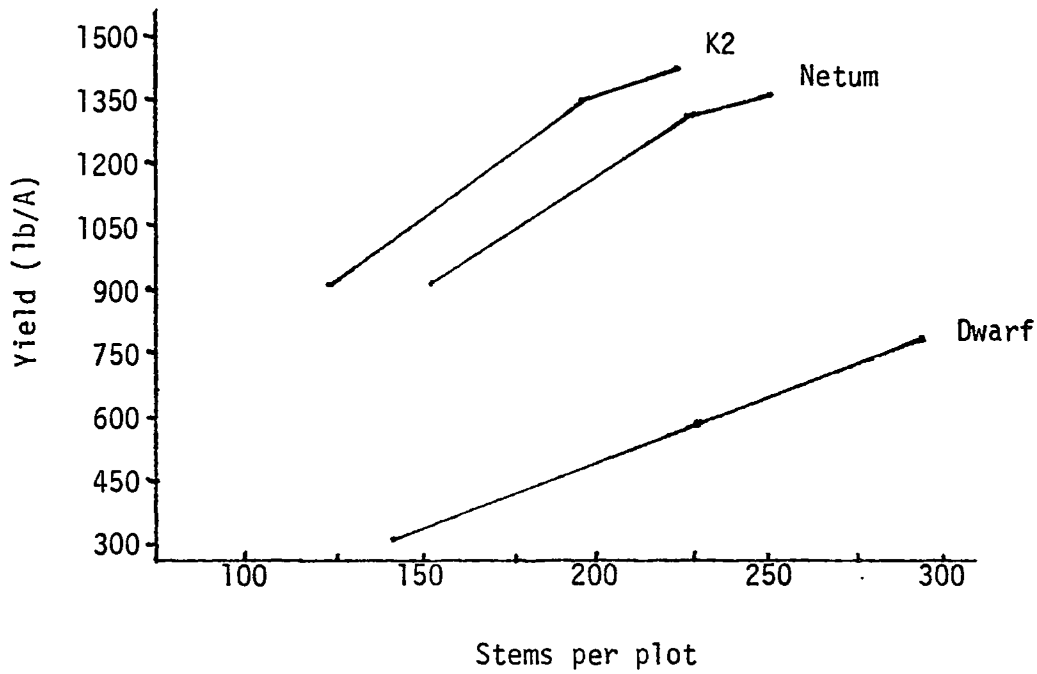

Figure 1. Yield per acre in relation to number of stems per plot for Dwarf, Netum and K2.

Table 7. Yield (lb/A of dehulled grain) of Dwarf, Netum and K2 at 2 levels of nitrogen and three planting densities at Grand Rapids on mineral soils.

Density[1/]	Dwarf		Netum		K2	
	N1	N2	N1	N2	N1	N2
1	289	440	770	909	838	901
2	529	674	1111	1337	1141	1478
3	799	785	1108	1235	1295	1387

LSD (.05) = 240 lb/A for comparing values within a variety.

Mean yield of plots receiving 15 lb. of N = 875 lb/A
Mean yield of plots receiving 55 lb. of N = 1016 lb/A

LSD (.05) = 81 lb/A

[1/] Planting rates were 8, 16 and 24 seeds per linear foot of row, respectively.

VI. Evaluation of competition from border rows in experiments using row plantings

Competition among plants for space, nutrients and light has been documented in most agronomic crops. Plants with available space are known to compensate for lack of plant density by increasing tillering and yield. Our nurseries and experiments are planted with skip rows between plots to enable us to take notes with confidence and to facilitate harvesting. To ensure equal competition between rows, we use 4-row plots and discard the outside two rows at harvest. Since the center two rows have been bordered, the plants have been evaluated with uniform competition for between-row space.

If seed supply is limited as will be the case when we evaluate plant progenies, we cannot use replicated 4-row plots. A question of importance, then, is how much compensation for space will occur in single-row plots with blank adjacent rows? Two-row unbordered plots could also be used. In 2-row unbordered plots, competition between the 2 rows would occur but compensation could occur on the outside of each row.

The purpose of this experiment was to determine the importance of yield compensation when unbordered plots are used. We evaluated 4 plot types:

a) single-row plots (unbordered)
b) single-row plots (bordered)
c) two-row plots (unbordered)
d) two-row plots (bordered).

Two varieties, M3 and Netum, were planted in 3 replicates of a randomized complete block design at Grand Rapids. Within each block-variety combinations, we repeated the 4 plot types 3 times. At harvest we discarded the border rows and recorded plant number, stem number and yield on the test rows. The green rice was dried and dehulled to express yield as grams of dry grain per row. To make the data comparable, the 2-row plot data were expressed on a per-row basis. An example of plot layout would look as follows:

```
0X0+X+0+XX+0XX0
0X0+X+0+XX+0XX0
0X0+X+0+XX+0XX0
0X0+X+0+XX+0XX0
0X0+X+0+XX+0XX0
 a  b   d   c
```

Where X = plants to be harvested
+ = plants for border rows (discard)
0 = skip rows not planted

The plots were 15 feet long and were end trimmed to 12 feet at harvest. Rows and skip rows were 1 foot apart.

If no compensation for space occurs, the results should show no significant difference for plot type. If compensation is important, the single row bordered plots should yield similarly to the 2-row bordered plots; the single row unbordered plots should be the highest in yield; and the 2-row unbordered plots should be intermediate between the single row unbordered plots and the bordered plot types.

The averages of the plot type comparisons are shown in Table 8. The means are averages over the two varieties and 9 repetitions. The stand densities (plants per plot) were not affected by plot type but stem number, stem number per plant and grain yield showed striking compensation from lack of border rows. There is little doubt that use of single row or 2-row unbordered plots will result in increased tillering and grain yield in comparison to the bordered plots. The two bordered plot types were not significantly different in effect from competition.

As indicated, the results are not surprising. We could still use unbordered plots in selection experiments for yield if all genotypes showed a similar ability to compensate for the available space. We had only two varieties in this experiment. The means for each variety at single row unbordered planting and single row bordered planting are shown in Table 9. M3 showed signficantly higher yield than Netum in single row unbordered plots but the same yield when evaluated in single row bordered plots. Plant number and stems per plot did not show significant interaction. Stems per plant, however, did show significant interaction. Netum tillered considerably more in unbordered single rows compared to the bordered single row plots.

The unequal number of plants per plot prevent a sound conclusion from this experiment regarding genotype X plot type interaction. The experiment has been fall planted (1981) at Rosemount to obtain a second year of data. At some time soon, we need to evaluate more varieties in this type of experiment. The significant question involves our ability to select high yielding families in single row plots. The results from this year's experiment leave open the possibility that the good yielding genotypes in row plantings may not be the good yielding genotypes in broadcast stands. They also emphasize the importance of additional knowledge on optimum stand density in growers' fields. M3 appears to have a greater capacity to use additional space than does Netum.

VII. Advanced yield trials

The advanced yield trials are used to obtain data on established varieties and to make decisions about promising experimental populations. Our primary interest in 1981 was the performance of K2E(2). Results on K2E(2) from the advanced yield trials have already been presented in the opening section of this progress report. Additional comments and information on the other entries will be discussed here.

The advanced yield trial at Grand Rapids was fall planted in 1980 and the trial at Excelsior was spring planted. Nine entries were evaluated: K2, K2E(1), K2E(2), M3, M3E(2), Netum, Experimental 3, M3xNetum, and M1. K2E(1) and K2E(2) resulted from 1 and 2 cycles, respectively, of selection for early flowering in K2. K2E(1) is included here as a check on selection

Table 8. Effect of border row competition in wild rice plots. (Means of 12 foot plots, replicated 9 times and averaged for Netum and M3.)

Plot type	Plants per row	Stems per row	Stems per plant	Yield[1/] per row
Single row	31	143	5.0	113
Two rows	31	123	4.5	89
Three rows[2/]	29	103	3.5	72
Four rows[3/]	30	107	3.7	74
LSD (0.05)	ns	16	.5	12

1/ Yield in grams of dry dehulled grain.
2/ Single row with border rows.
3/ Two-row plot with border rows.

Table 9. Comparison of Netum and M3 evaluated in single row unbordered plots and single row bordered plots. Grand Rapids.

	Grain yield[1/] (g)		Plant number	
Plot type	Netum	M3	Netum	M3
Single row (unbordered)	100	126*	21	40
Single row (bordered)	72	72	24	37
LSD (0.05)		18		ns
	Stems per plot		Stems per plant	
	Netum	M3	Netum	M3
Single row (unbordered)	127	159	6.0*	4.0
Single row (bordered)	96	110	4.0	3.0
LSD (0.05)		ns		1.2

1/ Yield of dry dehulled grain in grams per 12 foot row.

* Variety x plot type interaction is significant at 95% probability.

progress. It has now been discarded. M3E(2) was developed by 2 cycles of selection for early flowering in M3. Experimental 3 is an early version of Netum, which was selected for increased seed retention. M3xNetum is a population cross of early plants from M3 with Netum, after which the resulting plants were subjected to another cycle of selection for early flowering. Details on the procedures involved can be found in the 1979 and 1980 Wild Rice Progress reports.

The entries were planted in 4-row plots, 10 feet long, with a skip row between plots. Six replicates of a randomized complete block design were planted at each location. Flowering dates were recorded. At harvest the border rows were discarded and stand counts, stem counts, yield and percent recovery (based on dry dehulled grain as percent of green weight) were obtained for each plot. Height measurements were taken at Grand Rapids. The Excelsior planting developed brown spot which appeared to threaten the trial. However, the disease did not continue to develop and we were able to obtain good data on all but Experimental 3. A subjective disease score was recorded for each plot using a 0 (no damage) to 5 (badly damaged) scale.

Our primary purpose with the Grand Rapids trial was to assess the earliness of K2E(2) relative to Netum. Therefore, we harvested all entries but M1 and M3 on either August 19 or August 20. The yields obtained reflect the stage of development at that date. An earlier variety should yield more than a later variety.

Our primary purpose with the Excelsior trial was to assess the yield of the varieties when they were all at the same stage of maturity, i.e. when each normally would be harvested.

The results of the Grand Rapids trial are given in Table 10. Since most of the pertinent comparisons were discussed in the first section of our progress report, we will only make additional comments here. The progression K2 to K2E(1) to K2E(2) is a very good test of gain from selection for earliness and a test of any other traits that might have changed because of that selection. We were pleased with all of the maturity indicators. The height of the 3 populations suggests that height is somewhat reduced because of selection for earliness. In this test, K2E(2) was on the average about 6 inches shorter than K2. Tillers per plant were practically identical. K2E(2) is clearly earlier than K2 since at the same date of harvest, it had 6.5 percentage points better recovery, and 138 lb. per acre more grain (dehulled and clean). Both values are significant based on 95% probability.

We have two other experimental populations under development. M3E(2) is 13 days earlier flowering than M3, 2 days earlier than Netum, and 1 day earlier than K2E(2). It was about 5 inches shorter than M3, had 7.5 percentage points better recovery on August 20 than did M3 on August 26, and yielded 130 lb. more on August 20 than M3 on August 26. On August 20, M3 was so immature harvest did not seem worthwhile for comparative purposes. M3E(2) was 149 lb. better yielding than K2E(2). We will be continuing selection in M3E(2) in an attempt to increase uniformity of plant type, seed retention, and yield if possible.

Table 10. Flowering date, harvest date, height, tillers per plant, % recovery and yield of entries in advanced yield trial at Grand Rapids. (Harvest date chosen to illustrate effect of maturity differences on yield and percent recovery.)

Entry	Flowering date	Harvest date[1/]	Height (cm)	Tillers per plant	Recovery (%)	Yield[2/] (lb/A)
Exp. 3	7-3	8-19	178	5.0	44.1	638
Netum	7-8	8-19	185	6.7	38.2	557
K2	7-14	8-19	202	5.6	33.3	514
K2E(1)	7-10	8-19	192	5.7	38.0	662
K2E(2)	7-7	8-19	187	5.6	38.9	648
M1	7-17	8-26	210	5.6	35.5	662
M3	7-19	8-26	212	7.2	33.6	667
M3E(2)	7-6	8-20	201	8.2	41.1	797
M3 xNet	7-6	8-19	193	6.4	41.9	797
LSD (0.05)	-	-	12	1.6	3.1	130

1/ Harvest date was chosen. We wanted to demonstrate that K2E(2) was definitely earlier than K2. Note yield increase due to earliness and difference in % recovery.

2/ Yield in pounds per acre of clean dry dehulled grain.

M3xNetum had similar characteristics to M3E(2). The results of 2 cycles of selection for earliness are obvious for flowering date and % recovery. We will continue development of this population. Subsequently, M3E(2) or M3xNetum might be released but not both because of their similarity.

Experimental 3 was the earliest entry in the test, had the highest recovery percentage since it was very ripe on August 19, and had higher (although not significantly better) yield than Netum. Unfortunately for Experimental 3, it was almost destroyed by brown spot at Excelsior.

The results from Excelsior are presented in Table 11. The test was more variable in stand density than the Grand Rapids test. The disease incidence was an obviously important factor for Experimental 3 and to some extent for Netum. Our disease ratings, averaged over the six replicates, showed significant differences among entries. K2, K2E(1) and K2E(2) were not significantly different. M3E(2) had the least disease. The subjective nature of the ratings should be kept in mind. Nevertheless, based on disease incidence in the paddy, we know that Experimental 3 was almost wiped out while the M3E(2) had very little damage. This is not solely a function of disease resistance, however. The disease developed at a critical stage for Experimental 3. The environmental conditions must have changed at that time because no further disease development occurred in the plots. Short early lake collections in an adjacent paddy also were almost destroyed while tall later collections showed only minor incidence of disease.

The primary purpose of the test was to evaluate the yield of K2E(2) relative to K2 and to Netum. Individual plots were harvested when, in our best judgement, they were at an optimum stage--dark kernels on most tillers but shattering on main stem not yet severe. The mean date of harvest for each entry averaged over the six replicates is in Table 11. The range in percent recovery indicates that we did a reasonable job of harvesting the entries at nearly the same stage of maturity. The mean harvest dates for K2 and its derivatives were satisfying as were flowering dates. K2E(2) was significantly earlier than both K2 and K2E(1) and was significantly earlier than Netum for harvest date.

I believe the differences in number of tillers per plant for the K2 relatives were a function of quality of the yield trial. By chance, K2E(1) occurred on good plots and over the six replicates number of tillers and yield per plot were fairly uniform. K2 and K2E(2) both had plots in 2 of the replicates which were clearly poor in performance. Likewise, the high yield of K2E(1) relative to K2 or K2E(2) was largely a function of the quality of the test; K2E(1) had no obviously poor plots. The yields of M3, M3E(2) and M3xNetum also standout. They had good stands, uniform number of tillers and rather uniform yields over the six replicates.

Disease could have been a factor. The correlation between mean disease score and mean yield was a negative .95. Interpreted: those entries with low disease score had high yield; those with intermediate scores had intermediate yields and the two entries with high disease scores had low yields. Disease resistance itself is not indicated by the correlation. Yield was also highly correlated (positively) with number of tillers per plot (data not reported), and number of tillers per plot was established well before the disease occurred.

Table 11. Flowering date, harvest date, tillers per plant, % recovery and yield of entries in advanced yield trial at Excelsior. (Harvest date based on maturity of individual plots.)

Entry	Flowering date	Harvest[1/] date	Tillers per plant	Recovery[1/] (%)	Yield[2/] (lb/A)	Disease[3/] score
Exp. 3	7-12	8-15	3.4	46.4	278	4.3
Netum	7-14	8-20	3.5	49.7	581	3.3
K2	7-19	8-22	3.8	49.4	682	2.2
K2E(1)	7-15	8-18	5.3	52.0	850	1.8
K2E(2)	7-13	8-15	4.4	50.8	682	2.7
M1	7-19	8-25	3.8	51.8	763	2.2
M3	7-21	8-26	4.1	50.3	854	2,3
M3E(2)	7-15	8-21	5.2	53.5	888	1.5
M3xNet	7-13	8-19	4.9	52.0	802	1.8
LSD (0.05)	2	2	1.1	2.8	192	1.0

1/ Each plot was harvested when it was considered mature. Thus, recovery percentages, as a measure of maturity, should be similar.

2/ Yield in pounds per acre of clean dry dehulled grain.

3/ Disease was rated on a score of 0 = no disease to 5 = destroyed.

While the 1981 data were encouraging with regard to maturity evaluation, they were limited in establishing yield differences. We are very interested in the more extensive testing planned for next year. Experiments were fall planted at Paul Imle's and John Gunvalson's paddies, at Pete Olson's paddies and at Grand Rapids and Rosemount. We intend to make spring plantings at Grand Rapids and at Excelsior.

VIII. A comment on reporting of yield data

This year we have reported yields as pounds of dry dehulled grain per acre. The green seed from each plot was weighed at harvest and the samples were dried in forced air ovens. The dried samples were stored and when time permitted, we dehulled each sample using John Strait's dehuller. The chaff was removed with his blower and the remaining grain was weighed. The process is time consuming and therefore expensive. We hope this expression of yield is of more value than our former expression of yield at 40% moisture.

Some of our samples were also sized using Strait's shaker screens. We have not analyzed all of the resulting data--dry grain expressed in size fractions. The means of entries in the Excelsior advanced yield trial are given in Table 12. I analyzed only the percentages of the size 4 fraction. Differences among means averaged over the 6 replicates were significant at the 90% level of probability. I expected to see a greater differential distribution of seed in the size classes than was found. The separation into classes is based largely on seed width. The genetic variation for seed width may be small. A conclusion is that the distribution of dehulled grain in the size classes is more a function of maturity of the plant at time of harvest than it is of the genotype of the entry. This is going to require much more experimentation since it has important implications if we ever try to select for seed size.

Table 12. Mean percent of total dry grain (dehulled) in each of 4 size fractions of the seed from entries in the Excelsior advanced yield trial.

Entry	Size of fraction			
	4[1]	3.5	2.5	Remainder
Exp. 3	34[2]	37[3]	25	4
Netum	30	41	28	3
K2	31	39	26	4
K2E(2)	31	42	23	3
M1	37	38	22	3
M3	36	39	22	2
M3E(2)	43	38	18	2
M3xNet	33	41	23	3
LSD (0.10)	7	--Anova not computed--		

[1]Screen sizes (4 = 4/64 inch; 3.5 - 3.5/64 in., and 2.5 = 2.5/64 in.) are measures of width of the slots in the screen.

[2]% ot total dry grain weight that was retained on size 4 screen.

[3]% of total dry grain weight that was retained on size 3.5 screen but which went through the size 4 screen.

Acknowledgements

We would like to thank the following people for their help, assistance in support funds and/or service during the past year:

Joe Rust, Jim Boedicker and Dave Rabas--Grand Rapids;
Clifford Wilcox, Ken Walter and Dave Sandstrom--Rosemount;
Gerald Ochocki, Hort. Research Center, Excelsior;
John Strait, Cletus Schertz and Mike Lueders, Agricultural Engineering, St. Paul; and
The Minnesota Crop Improvement Association.

I would like to convey my appreciation to Gary Linkert, Henry Schumer, Les Everett, Larry Boze, Wally Palm, Louise Fluegeman and Jana Campbell for their positive attitude, good humor and interest in their work.

WILD RICE DISEASE RESEARCH - 1981

A PROGRESS REPORT

January 23, 1982

James A. Percich, Project Leader
Elizabeth Smallwood, Research Associate

In 1981 the Plant Pathology Wild Rice Project completed studies involving the identification, distribution and biology of several bacterial and fungal pathogens of cultivated and natural stands of wild rice. The specific areas of investigation were the following:

1) Continuation of a crop-loss study utilizing defoliation which simulated the leaf loss that would occur due to an infection by a foliar pathogen.

2) The effect of Helminthosporium sigmoideum, causal agent of stem rot of commercially grown wild rice on yield, grain size and lodging.

3) Foliage disease survey of commerical fields.

4) Completion of a three year study of two bacterial pathogens of wild rice.

5) Completion of a three year research project (Rockerfeller Foundation) examining fungicide tolerance in Bipolaris oryzae (Helminthosporium oryzae) and B. sorokiniana (H. sativum), the causal agents of fungal brown spot of wild rice.

6) Completion of a two year study of zonate eyespot of wild rice, caused by Drechslera gigantea.

METHODS AND MATERIALS

CROP LOSS - DEFOLIATION STUDY

In 1981 a section of a paddy at the North Central Experiment Station at Grand Rapids, Minnesota was planted with the cultivar K-2 utilizing a randomized block design. Five 50 x 50 ft (15 x 15 m) blocks, each containing ten 50 ft (15 m) rows and having 50 plants at 1 ft (0.3 m) intervals were fall planted. A defoliation consisting of one-half of every leaf on each test plant was performed at the following stage of plant development:

Defoliation	Date	Stage of Development
A	June 24, 1981	Tillering
B	July 2, 1981	Jointing-Boot
C	July 16, 1981	Late flowering
D	July 29, 1981	Grain Filling (Milk to Soft Dough)
E	August 24, 1981	Maturity (Dark Kernels)

Each defoliation was replicated in 10 test plots. The control plots were not defoliated but were allowed to grow and mature normally. Leaf material was removed from a randomized sampling of ten treated plants and then taken into the laboratory and placed in a computerized instrument which recorded leaf area. All plots were sprayed with each of two applications of Dithane M-45 plus Triton B-1956 and Bravo 6-F at 2 lbs. per acre in 30 gal of water to control *Bipolaris* spp. infection. All yield data was expressed as dry weights.

STEM ROT OF WILD RICE

A second year study of the effect of *Helminthosporium sigmoideum* on yield and lodging of cultivated wild rice was conducted at St. Paul in 3' x 6' (91.5 x 182.9 cm) fiberglass tubs (cement forms) which were flooded to a depth of 5 in (12.7 cm) of water. The tubs contained 15 in (38.1 cm) of peat soil. Fungal sclerotia (overwintering survival structures) were introduced in each tub during various stages of plant development, excluding the controls.

Green weight yields consisted of three pickings over a two week period. At each harvest period, the seed was collected by rapping the rice heads against the side of a collection container to dislodge ripened kernels. A final harvest (rasp bar threshing) was taken one week after the third picking.

The diameter of dried dehulled seed constituted the measurement for seed quality. The largest diameter of 4 mm was considered the "highest grain quality".

A stalk rot incidence and severity survey was made utilizing 20 different growers and a total of 46 fields. The fields were broken down into different age classes (1, 2, ... 6 years) depending upon the period of continuous wild rice culture. At least 5 fields at each age class was examined for the presence and percent infection by H. sigmoideum. Fifty plants at random were examined in each field.

FOLIAGE DISEASE SURVEY

On July 6-8, July 20-22, August 11-13 and August 25-27, 1981, twenty-two commercial fields were surveyed for foliage diseases. A disease index (ID) consisting of a 0 to 9 scale indicating 0 to more than 50% leaf infection, respectively was used. Each field was visited 4 times and the respective disease ratings were then averaged. The diseases surveyed were brown spot (incited by Bipolaris oryzae and B. sorokiniana) bacterial leaf streak (Xanthomonas campestris and Pseudomonas syringae), Anthracnose (Colletotrichum sp.), zonate eyespot (Drechslera gigantea), smut (Entyloma lineatum) and "Phaeoseptoria leaf spot" (Phaeoseptoria sp.).

RESULTS

DEFOLIATION STUDY

Wild rice plants that were not defoliated and allowed to develop normally yielded 3962 grams on a dry weight basis (Table I) while plants that were defoliated at tillering, jointing-boot, late-flowering and grain filling had reduced yields of 410, 562, 958, and 862 grams, respectively when compared to the non-defoliated controls. All defoliation treatments, except at tillering, resulted in significant percentage weight loss when compared to the controls (Table I). Defoliation during the late flowering period of plant development caused the greatest significant reduction in yields.

Grain diameters as they relate to the time of defoliation were not significantly different.

Defoliation had no significant effect, regardless of the stage of plant development, on the ratios of grain size (>4mm, <4≥3mm, <2≥2mm) as compared to the untreated controls.

STALK ROT OF WILD RICE

The effect of Helminthosporium sigmoideum infection of wild rice cultivar K-2 at various stages of plant development was examined.

Plants which were inoculated during the aerial, tillering, heading and late flowering stages of development did not result in significantly reduced yields when compared to the uninoculated controls (Table 2).

The effect of H. sigmoideum infection at various stages of plant development on subsequent grain sizes at harvest was not significant Table 2). Also, no significant difference in the ratio of grain diameters > 4mm (highest quality) was found due to infection at various stages of plant development when compared to the controls.

Wild rice plants at the third picking were counted to determine the percentage of lodging present. Plants infected during the aerial, tillering, heading, and late flowering stages of development resulted in 72, 68, 68, and 76% lodging (Table 2). All treated plants had significantly more lodging than the uninoculated controls. However, regardless of age all plants which were infected, except at heading, did not have significantly reduced yields when compared to the controls Table 2).

The effect of Helminthosporium sigmoideum infection on total yield and the percentage of yield at various grown sizes was examined. Wild rice, cultivar K-2, plants were exposed to fungal sclerotia during the aerial leaf phase of development. Each treatment consisted of 5 replications, each containing 50 plants. Yield data was expressed on a dry weight basis. There was no significant difference in yields between the inoculated and control plants (Table 3). The three classes of grain diameters consisted of seed greater than 4 (>4), less than 4 but equal to or greater than 3 ($<4 \geq 3$) and less than 3 but greater than or equal to 2 millimeters ($<3 \geq 2$).

There were no significant differences between the inoculated and healthy control plants as to the relative percentages of grain sizes at harvest (Table 3).

Therefore, it appears at this time that the fungal pathogen Helminthosporium sigmoideum can infect wild rice at several stages of development, will not generally cause significant decreases in overall yields or quality of grain but will significantly increase lodging. It is presently unclear as to the role of H. sigmoideum infection has on the incidence and severity of lodging when coupled with the following:

1. Density of plant stand.

2. Insect infestation and role of secondary fungal and/or bacterial infections.

3. Fertilization levels, such as nitrogen and potassium.

4. Cultivar susceptibility.

5. Water depth and time of drainage.

Future research involving the above five factors alone or in various combinations with Helminthosporium sigmoideum must be undertaken before a sound preventative and/or control program(s) can be established.

HELMINTHOSPORIUM SIGMOIDEUM FIELD SURVEY

During the past three years of surveying growers' fields for incidence and severity of Helminthosporium sigmoideum a positive relationship between continuous wild rice cultivation and the percentage of plants infected could be observed. The survey consisted of visiting 20 different growers throughout the wild rice growing areas of Minnesota at or near harvest time. A total of at least 4 fields at various ages of continuous cultivation were observed and a random sampling of 50 plants per field was made for the presence or absence of H. sigmoideum. The following chart briefly summarizes the findings of three years of survey data:

Years of Continuous Wild Rice Cultivation	Percent Plants Infected
≥6	80
5	64
4	47
3	45
2	35
1	5

Therefore, increasing the period of continuous cultivation will increase the percent of plants infected. Even after only one year of cultivation H. sigmoideum could be found in 5% of the plants examined and by the 4th and 5th year the levels of infection had climbed to 47 and 67%, respectively. There is at the present time no data correlating the percent and severity of plants infected with *H. sigmoideum* with yield loss and the amount of potential lodging. Therefore, it may be wise to avoid growing wild rice for more than 3 years on the same field. However, it should be noted that this recommendation is based on field observations and not experimental results.

FOLIAGE DISEASE SURVEY: COMMERCIAL FIELDS

Brown spot symptoms had the highest average disease index severity rating (DI 4.6) as well as the highest individual ratings (Table 4). The second most severe disease was bacterial leaf streak (DI 1.6) which was found in all but one field state-wide. The other four diseases caused only minor damage in 1981 (Table 1).

Since the brown spot symptom can be caused by three different organisms (*Bipolaris oryzae*, *B. sorokiniana*, *Pseudomonas syringae*), selected isolations from 12 commercial fields were made to determine which was the most important causal agent. *Bipolaris oryzae* in 1980 and 1981 was isolated from disease tissue 55 and 63% of the time, respectively (Table 5). In 1981 *Bipolaris sorokiniana* and *P. syringae* were found in 4 and 26% of the infected leaf material (Table 5).

In a single limited survey of natural stands, *B. sorokiniana* was consistently dominant over *B. oryzae*. Therefore, it appears that the dominance of *B. oryzae* and *B. sorokiniana* is reversed in natural and commercial stands. These findings are consistant to the more intensive, 1980 survey which indicated that *B. oryzae* could only be found at one of 6 lake sites.

After two years of surveying commercial fields and natural stands the following conclusions can be made:

1. Brown spot disease, incited by *B. oryzae* is the major foliage disease of commercially-grown wild rice in Minnesota.

2. Research for the development of new chemicals and cultural practices, as well as disease resistant varieties to help manage brown spot, incited by *B. oryzae* should continue.

3. Bacterial leaf spot, incited by *Pseudomonas syringae* is easily confused with brown spot caused by *B. oryzae* and in some cases can result in serious damage.

4. In natural stands *Bipolaris sorokiniana* is the major foliar pathogen but generally the percent of leaf infection is less than 5 percent.

TABLE 1 THE EFFECT OF A 50% DEFOLIATION OF WILD RICE AT FOUR DIFFERENT PHASES OF PLANT DEVELOPMENT

	TREATMENT WEIGHT	WEIGHT LOSS COMPARED TO CONTROL	PERCENT WEIGHT LOSS COMPARED TO CONTROL
TILLERING	3552[A/]	410	10[B/]
JOINTING-BOOT	3400	562	14
LATE-FLOWERING	3004	958	24
GRAIN FILLING MILK-SOFT DOUGH	3100	862	22
MATURITY (NO DEFOLIATION)	3962	-	-

A/= Dry weight in grams

B/= Not significant at the 5% level

TABLE 2 THE EFFECT OF HELMINTHOSPORIUM SIGMOIDEUM INFECTION OF WILD RICE AT VARIOUS STAGES OF PLANT DEVELOPMENT

TREATMENT	TREATMENT WEIGHT[A/]	% OF YIELD WITH GRAIN DIAMETERS OF MORE THAN 4 MM (TREATMENT VS. CONTROL)	% LODGING	% LODGING COMPARED TO CONTROL
AERIAL[B/]	794	37:40	72*	38
TILLERING	830	34:39	68*	34
HEADING	706[C/]	34:39	68*	42
LATE FLOWERING	776	35:38	76*	42
CONTROL (NO DEFOLIATION)	828		34	

A/ DRY WEIGHT IN GRAMS OF 5 REPLICATES, EACH CONTAINING 50 PLANTS

B/ 3RD TO 5TH AERIAL LEAVES

C/ SIGNIFICANTLY DIFFERENT THAN CONTROL AT THE 5% LEVEL

* SIGNIFICANTLY DIFFERENT THAN CONTROL AT THE 5% LEVEL.

TABLE 3 EFFECT OF HELMINTHOSPORIUM SIGMOIDEUM INFECTION OF WILD RICE ON YIELD AND GRAIN SIZE

TREATMENT	YIELD	PERCENT GRAIN DIAMETER IN MILLIMETERS		
		>4	<4≥3	<3≥2
INOCULATED	794	37	55	8
CONTROL	808	37	57	6

TABLE 4 FOLIAGE DISEASE SURVEY: COMMERCIAL FIELDS

FOLIAGE DISEASE SURVEY - 1981

COMMERCIAL PADDIES

FIELD	COUNTY	VARIETY	SYMPTOM SEVERITY: BROWN SPOT	BACTERIAL LEAF STREAK	ANTHRACNOSE	ZONATE EYESPOT	SMUT	PHAEOSEPTORIA
1	AITKIN	JOHNSON	5	1	0	0	1	0
2	"	"	5	1	0	0	1	0
3	"	"	9	3	1	1	1	0
4	"	K2	3	3	1	0	1	0
5	"	"	9	3	1	1	1	0
6	"	"	7	1	1	0	1	1
7	"	"	3	3	0	0	1	0
8	"	"	5	1	1	1	1	1
9	"	M1	3	1	1	0	1	1
10	BELTRAMI	K2	5	1	1	0	1	1
11	"	"	3	0	0	0	1	0
12	"	JOHNSON	9	3	3	3	1	0
13	"	"	5	1	3	1	1	0
14	"	"	3	1	1	1	1	0
15	"	NETUM	1	1	1	1	1	0
16	CLEARWATER	NETUM	3	1	1	3	1	0
17	"	"	1	1	1	3	1	0
18	"	JOHNSON	5	1	1	0	1	0

TABLE 4 (CONTINUED)

FIELD	COUNTY	VARIETIES	BROWN SPOT	BACTERIAL LEAF STREAK	ANTHRACNOSE	ZONATE EYESPOT	SMUT	PHAEOSEPTORIA
19	CLEARWATER	JOHNSON	5	3	1	1	1	0
20	"	"	5	1	0	1	1	0
21	POLK	K2	3	3	0	0	1	0
22	"	"	3	1	0	1	1	0
		AVERAGE 1981	4.6	1.6	0.7	0.8	1.0	0.2
		AVERAGE 1980	2.8	1.2	0.3	0.1	1.0	0.1

SCORING SYSTEM

0 = 0% OF LEAF AREA AFFECTED

1 = LESS THAN 1% OF LEAF AREA AFFECTED

3 = 1 TO 5% LEAF AREA AFFECTED

5 = 5 TO 25% " " "

7 = 25 TO 50% " " "

9 = MORE THAN 50% LEAF AREA AFFECTED

TABLE 5 PERCENTAGES OF VARIOUS ORGANISMS ISOLATED FROM COMMERCIALLY GROWN WILD RICE PLANTS HAVING BROWN SPOT SYMPTOMS

SURVEY[B/]	PERCENTAGE OF ISOLATIONS[A/]		
	B. ORYZAE	B. SOROKINIANA	P. SYRINGAE
1980	55	6	31
1981	63	4	26

A/ PERCENTAGES DO NOT NECESSARILY ADD TO 100% BECAUSE SOME PLANT SPECIMENS YIELDED MORE THAN ONE ISOLATE WHILE OTHERS YIELDED NONE

B/ SURVEY CONSISTED OF 12 COMMERCIAL PADDIES

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ACKNOWLEDGMENTS

Special thanks to Mr. Henry Schumer and his staff at the North Central Experimental Station, Grand Rapids and to Mr. Clint Kohls, Graduate Assistant for their help and support in 1981 is greatly appreciated.

SPIKE TOOTH AND RASPBAR CYLINDER COMPARISONS AND FEED RATE INFLUENCES ON COMBINE PERFORMANCE

Cletus Schertz, James Boedicker, and Michael Lueders
Agricultural Engineering

The 1981 wild rice harvest research was directed toward: 1) further development of the combine discharge sample collector system for adaptibility as required for combines of different manufacture, 2) development of a new concept for quick retrieval of lost grain from combine discharge samples, and 3) evaluating the influence of a) cylinder type (spike tooth or raspbar) and b) feed rate on combine performance.

Combine Discharge Sample Collector

Combines of different manufacture vary widely in design at the rear where discharge samples are collected. Variations include differences in rear wheel size and spacing, differences in location of rear axle and/or hitch point with respect to walker and sieve discharge locations, among others. Because of the wide variation in combine design at the rear, it may be impractical to develop a single collector frame with sufficient adjustment capability that it can be used on all combines.

Our goals for the 1981 harvest season included collecting discharge samples from two different makes of combines. Considering this goal, it was most expeditious to develop two separate collection frames, each identical in concept to that described in the 1979 and 1980 reports; but, each with the necessary flexibility of adjustment to fit behind differently configured combines. This was necessary because one of the combines was particularly restrictive in access to the discharge material. This restrictive access was caused by the rear tires being large, narrowly spaced and located nearly within the combine discharge zone. The catch cloths on each frame were power actuated to reduce human error in opening and closing the catch cloths compared to a rope-pull system.

Retrieval of Lost Grain from Discharge Samples

The development and evaluation of a new concept of using a water separator for quick retrieval of lost grain from combine discharge samples is described in another chapter authored by Boedicker et al. The water separator was effective in reducing the on-site time required, compared to previous years, to obtain discharge loss data. The data in this report on combine evaluation indicates the on-site data available, which was available this year, within 24 hours of collecting the group of discharge samples. A shorter turnaround can be achieved. The actual time to retrieve the lost grain from a sample and establish the "on-site" data is ½ - 1½ hours. This time includes only the time to obtain the walker and sieve losses and not the threshing losses. Retrieval of the threshing loss requires subsequent drying of the straw and a series of processing events.

Influence of Cylinder Type

At Site I comparisions were made of combine performance as influenced by type of cylinder and concave. Two nearly identical combines were used, one equipped with a spike tooth cylinder and concave and the other with a raspbar cylinder and grate concave. Table 1 shows the data for these comparisons. Although limited data was obtained, the following points should be considered:

1. The raspbar cylinder had lower loss level for both walker and sieve losses than the spike tooth.

2. The MOG (Material Other than Grain) rate over the sieves for the raspbar was approximately 2/3 that of the spike tooth whereas the total MOG averaged the same. The raspbar does less tearing up of the straw and therefore reduces the MOG rate on the sieves.

3. For the raspbar the loss over the sieves was about equal to the losses over the walkers. It is appropriate to have this balance. This condition suggests that both of the combine separating systems are receiving equivalent loadings. In contrast, for the spike tooth, the sieve loss is 50% greater than the walker loss.

Influence of Feed Rate

At Site II a series of runs were made to look at the influence of MOG (Material Other than Grain) feed rate on discharge losses. Results of this are shown in Table 2 and Figure 1.

The feed rate was altered by changing the travel speed, but crop material density also had influence on the MOG feed rate. The calculation of MOG feed rate was determined by weighing the material collected in a prescribed distance and by calculating from other measurements, the travel time for this distance.

Some observations of these results are:

1. The walker loss rises sharply with a MOG feed rate greater than 250 - 300 lb/min (Fig 1).

2. The sieve is more drastically influenced by increase in MOG feed rate than the walker.

3. The loss level, as obtained on-site, parallels the loss level obtained from drying and evaluating on basis of dry weights of loss material and net yield. The data evaluated from drying

Table 1. Data from Site I (Evaluation of raspbar cylinder and spike tooth cylinder)

Run No. 81-	Travel Speed[h] Mph	Net Yield, Green lb/ac	MOG (Material other than grain) rate: Over Walker lb/min	Over Sieve lb/min	Total lb/min	Total lb/ac	Discharge[a] Losses: walker[c] % of Net	sieve[c] % of Net	Discharge[b] Losses: walker[d] % of Net	sieve[e] % of Net	
101	1.4	919	311	12.0	323	7560	0.8	0.1	1.8	1.7	f
102	1.7	841	279	--	--	--			1.5	--	f
103	1.6	763	216	11.2	227	4910			1.4	1.3	f
104	1.8	760	215	15.2	231	4500			1.1	1.2	f
Avg		821	255	12.8	260	5660			1.4	1.4	
105	1.6	802	236	18.9	255	5580	1.4	0.3	3.0	4.7	g
106	1.9	721	180	14.6	195	3570			1.2	3.2	g
107	1.6	814	282	22.3	304	6490			4.4	5.3	g
108	1.3	~~511~~	--	--	--	--			--	--	g
Avg		779	233	18.6	251	5210			2.9	4.4	

a) As evaluated at completion of on-site processing (partial drying, not dehulled and compared to green weight of net yield).

b) As evaluated by drying (not dehulled) the loss material and comparing to dry weight equivalent of net yield.

c) only sink portion (floaters from water separator not included)

d) both sink and float portion from water separator included

e) both sink and float for 101 and 105 but by fanning for others

f) Raspbar cylinder and grate concave

g) Spike tooth cylinder and concave

h) The rows were in the sequence shown and for the latter run(s) dew had settled on the crop.

Table 2. Data from Site II (Evaluation of influence of MOG feed rate on discharge losses)

Run No. 81-	Travel Speed[h] Mph	Net Yield, Green lb/ac	MOG (Material other than grain) rate: Over Walker lb/min	Over Sieve lb/min	Total lb/min	Total lb/ac	Discharge Losses[a]: walker[c] % of Net	sieve[c] % of Net	Discharge Losses[b]: walker[d] % of Net	sieve[e] % of Net	
201	1.3	1070	--	--	--	--	0.3	2.5	0.5	2.6	f
202	1.0	645	52	3.0	55	1720	0.1	1.1	0.2	1.1	f
203	0.9	784	80	3.0	83	2670	0.1	0.6	0.3	0.6	f
301	1.4	1180	148	6.0	154	3650	0.2	0.5	0.3	0.5	g
302	1.5	1040	153	6.4	160	3640	0.2	1.3	0.3	1.4	g
303	1.4	1040	184	9.9	194	4590	0.4	2.6[i]	0.7	2.8[i]	g
304	0.8	1190	83	3.8	87	3720	0.1	0.2	0.2	0.3	g
305	0.7	1530	82	4.7	87	4070	0.2	0.2	0.3	0.2	g
306	0.8	1430	104	4.5	108	4820	0.2	0.4	0.4	0.4	g
307	2.0	860	117	--	--	--	0.2	--	--	--	g
308	2.0	1200	259	11	270	4620	0.5	2.1	1.0	2.3	g
309	1.9	1060	223	8.7	232	4240	0.4	2.2	0.7	2.3	g
310	--	--	--	--	--	5170	--	--	--	--	g
311	2.8	--	357	16.7	374	4600	--	--	--	--	g
312	3.0	820	294	14	308	3420	1.5	3.0	2.6	3.4	g

a) As evaluated at completion of on-site processing (partial drying, not dehulled and compared to green weight of net yield).

b) As evaluated by drying (not dehulled) the loss material and comparing to dry weight equivalent of net yield.

c) Only sink portion (floaters from water separator not included).

d) Processed by fanning (water separator not used).

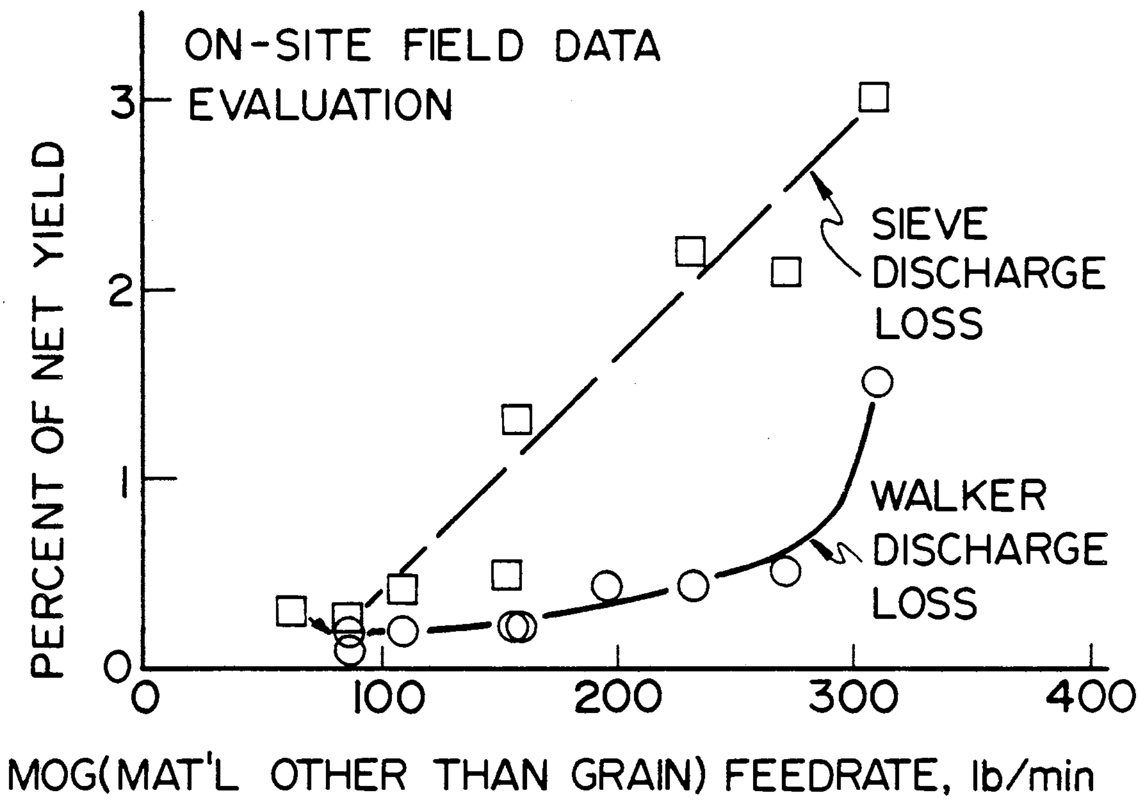
e) Both sink and float portion from water separator included.

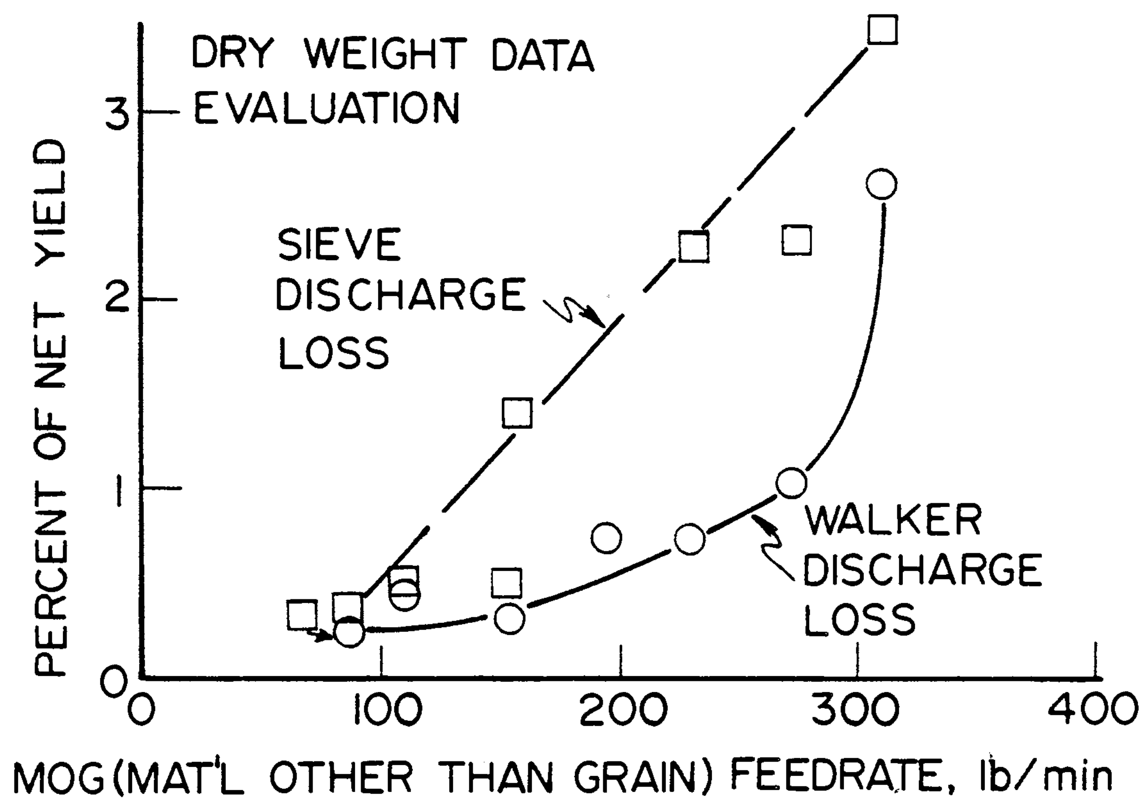
f) Shake down runs to check out the procedures.

g) Feed rate variation runs.

h) Actual travel speed in test area. It is felt that for runs 304 - 312 final speed adjustment from "normal" occurred too close to test area and may have influenced material flow rates. This problem arose because of improper instructions to operator.

i) Possible contamination of sample from accumulation on axle.


ON-SITE FIELD DATA
EVALUATION
SIEVE
DISCHARGE
LOSS
WALKER
DISCHARGE
LOSS
PERCENT OF NET YIELD
0
1
2
3
0
100
200
300
400
MOG(MAT'L OTHER THAN GRAIN) FEEDRATE, lb/min


DRY WEIGHT DATA
EVALUATION
SIEVE
DISCHARGE
LOSS
WALKER
DISCHARGE
LOSS
PERCENT OF NET YIELD
0
1
2
3
0
100
200
300
400
MOG(MAT'L OTHER THAN GRAIN) FEEDRATE, lb/min

(3 cont.)

is either equal or greater than the corresponding data from on-site evaluation. The on-site evaluation had inconsistent control of drying of the material before weighing. Even with this lack of control for on-site evaluation, the on-site evaluation would have been a good indicator.

4. MOG rate over the sieves is extremely low. The sieve samples were small enough that processing was achieved by brief air drying and then fanning.

5. The final adjustment of travel speed, for runs 304 - 312, too close to the test area may have influenced flow rates. For the slower runs, this would have increased net yield and for the faster runs this would have decreased net yield. Because of the short residence time of material in the combine this discrepancy in operation can account for only a small portion of the variations of net yield. Field variations influenced the variations in net yield.

Comparison of Net Yield, Travel Speed and Reel Index

At Site II, because of the wide variations in net yield, the need for more information relating to field variations was realized. An eleventh hour decision was made to make a series of runs with measuring only net yield with variations in travel speed and reel index. The data from this are tabulated in Table 3.

Reel index is the ratio of reel peripheral speed to travel speed. It's also the ratio of reel peripheral displacement to travel distance. Reel index has influence on the reel's gathering effectiveness (extent of pushing forward, extent of pushing rearward and tendency for the bat to slither between the plant stalks). The preferred reel index for most crops is 1.3 to 1.8. For wild rice the recommended reel index has not been defined.

The limited data of Table 3 does not establish the preferred reel index but points to a combine functional component that needs investigation relating to the wild rice crop.

Table 3. Comparisons of net yield, travel speed and reel index

Run No. 81-	Travel Speed Mph	Reel Index	Net Yield lb/ac
401	1.6	2.2	1100
402	1.5	2.4	728
403	1.5	2.4	841
404	1.4	1.9	864
405	1.1	2.4	1180
406	1.1	2.4	1190
407	.9	1.6	879
408	.8	1.9	804
409	.8	1.7	766
410	1.1	3.2	980
411	.9	3.8	1080
412	1.0	3.7	1040
		Avg.	953
		Std. Dev.	161

EVALUATION OF A WATER SEPARATOR FOR COMBINE DISCHARGE SAMPLE ANALYSIS

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Introduction

The development of satisfactory equipment and procedures for quick analysis of combine discharge samples in the field has been a significant challenge. In past years, we have used a specially modified parked combine, a tumbler, a rotary screen and numerous other devices to separate loose kernels from walker and sieve discharge samples, but none has proved satisfactory in our estimation. Furthermore, because we want to differentiate between threshing loss and walker loss, the use of these types of equipment required that heads be sorted from walker samples before attempting to separate loose kernels. Head sorting, which was done by hand is time consuming and subject to considerable error.

In 1981, an entirely different concept for loose kernel separation was used with the separation medium being water. Laboratory tests showed that on a dry, dehulled basis, 80 to 90 percent of the grain in samples of combined rice mixed into a container of water sank to the bottom while the rest floated. In other tests where combined rice straw with heads removed and with rice added was agitated in a large container of water, we were able to retrieve about 97 percent of the rice we had added. Included in the 97 percent figure was floating rice which was retrieved by skimming the surface while the buoyant straw was being held below the surface.

Equipment and Procedures

Encouraged by the above observations and by what we felt was an excellent chance that a water separation process would make sorting of heads in walker discharge samples unnecessary, we built a water separator for use during the 1981 season. Figure 1 shows the separator as it was set up near one grower's field.

Briefly, the separator consisted of a 10' x 2' x 4' (L x W x H) tank with a mechanically driven plunger inside. At the bottom of the tank were five inverted pyramid-like shaped sections for congregation of the sinkers. The tank was constructed of angle iron lined with galvanized steel sheet except for one long side which was a clear plastic material selected to permit observation of straw action in the tank. Lengths of clear plastic tubing (1-1/4" I.D.) connected by special adapters to the bottom of each section provided a means of sinker retrieval.

Inside the tank was a large rigid plunger designed and driven so that the combine discharge material would be alternately pushed down and allowed to rise and at the same time be moved along below the surface of the water from one end of the tank to the other. The plunger face material was 1" square wire mesh selected to permit only water and small pieces of plant material including rice kernels to pass while keeping the longer straw material confined

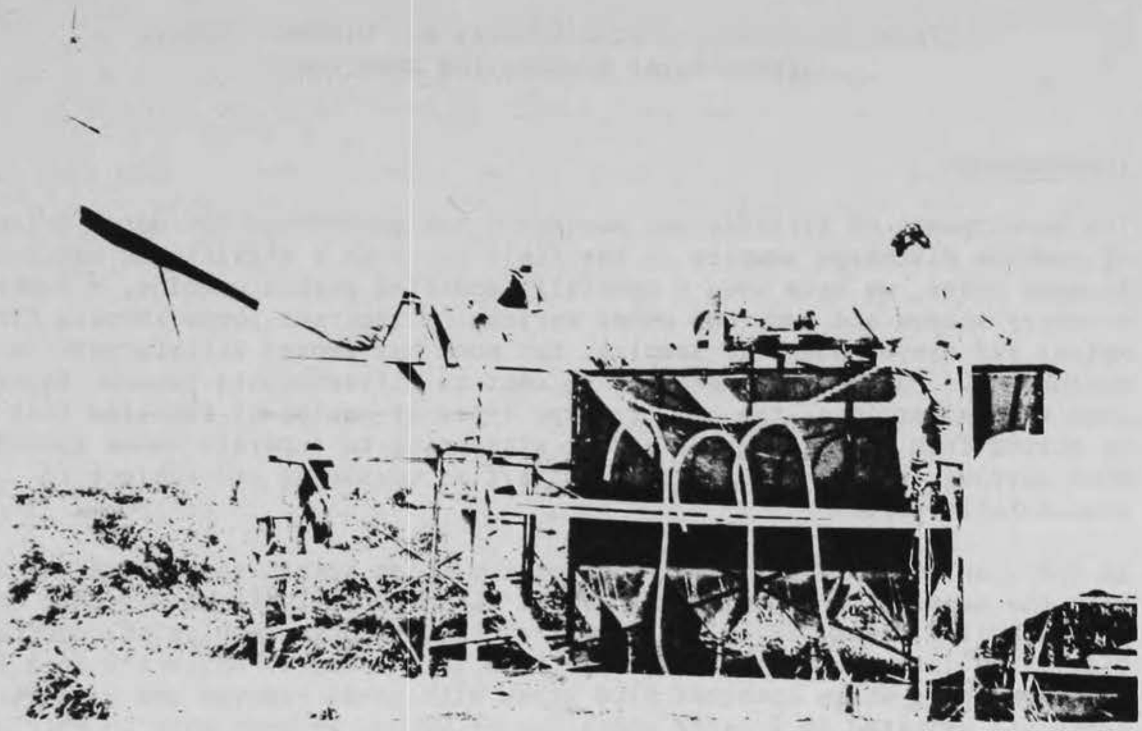

Figure 1. The water separator as it was set up near one growers field.

below. "Skirts" were provided on both sides of the plunger to confine the straw beneath the plunger while moving through the separator. The skirts were also made of clear plastic to permit observation of the straw action. The plunger was driven in a circular motion by a double, parallel acting eccentric system powered by an electric motor through a speed reducer and chain drive. A fixed-center variable speed pully drive from the motor to the speed reducer provided for a wide range of adjustment in plunger rpm. Plunger stroke was also adjustable over a range of 6 to 18 inches.

After the separator was built, preliminary tests were conducted with loose rice added to fresh-cut rice straw that had been "conditioned" in a plot thresher. The purpose was to observe general operating characteristics and to determine suitable plunger rpm and stroke. In terms of material action and movement through the tank, the separator performed quite well. A plunger rpm of 18 and a stroke of 14" provided what appeared to be satisfactory straw action. These settings were maintained for all tests in 1981. An unexpected observation during the tests was that floating material had a strong tendency to collect at the center of the tank, apparently as a result of water currents set up in the tank by the action of the plunger. This characteristic aided considerably in hand retrieval of the floating material at the conclusion of the test runs in the field. Plugging problems which occurred in the preliminary tests at the outlets of the bottom sections were eliminated in the field by frequent draining of the material accumulating at these points during each run.

The separator was equipped with a trough and slide at one end for feeding the combine discharge material into the tank. In the field, feeding and straw removal from the separator was done by hand. The straw taken from the separator was placed on plastic sheets which were then moved to an inclined surface so free water could drain. After draining, the material was dried in the sun as much as possible before being taken to St. Paul for further processing to remove additional rice which, in walker samples, was all considered to be threshing loss.

After each combine discharge sample had been run through the separator, the material left floating on the water surface was collected with hand strainers. Beyond this point in the procedure, material collected from the top and bottom of the separator from each run was treated in a similar manner. First, it was centrifuged by hand in plastic screening to remove excess water and it was then partially dried in a homemade drier to facilitate subsequent screening and fanning to separate rice kernels from other material--pieces of leaf, stem, etc.--collected along with the rice. The rice was then weighed and using estimates for its moisture content and that of combined rice, losses were calculated in terms of pounds of green rice per acre and percent of net yield.

Evaluation of Separator

With walker samples, it was our hope to be able to assess walker loss based on the amount of rice retrieved from the separator and threshing loss based on the amount of rice remaining with the straw. To obtain some estimate of the validity of this procedure, tests were devised to independently determine separation efficiency for loose kernels and retention percentage for attached (unthreshed) kernels.

To determine separation efficiency for loose kernels, a sizable quantity of rice straw was harvested by hand from a paddy, heads were removed, and the remaining material was fed through a parked combine to simulate combine discharge material. This material was then divided into two piles (replications) and 100 gram quantities of combine-harvested green rice was mixed with each pile. The material in each pile was then fed through the separator and sinking and floating material was retrieved and analysed later in St. Paul. The straw taken from the separator was also saved for later analysis to determine how much rice had come through with the straw. In a companion test, two 100 gram quantities of rice from the same source were mixed in a container of water and allowed to settle out to obtain estimates of the percentages of floaters and sinkers in the rice added to the straw. With these values, we were able to estimate separation efficiency for sinkers and floaters independently.

To determine retention percentage for attached kernels, a large quantity of walker discharge material was hand sorted to obtain two piles of material which were assumed to contain essentially no loose kernels. The material was then fed through the separator and sinking and floating material was retrieved and saved for later analysis. The straw from these tests also was taken to St. Paul for later processing to remove and separate the rice still attached to the heads.

Results of the evaluation test runs are contained in Table 1 and are given on a dry basis in two ways: not dehulled and dehulled.

In tests with headless straw with loose rice added, separation efficiency figures were nearly the same on both a dehulled and a not dehulled basis, averaging in the neighborhood of 93 to 95 percent. A comparison of these results with those of the companion sink-float tests with rice alone from the same source shows that separation efficiency for sinkers was virtually 100 percent (both basis) while that for floaters was 52 percent (not dehulled) and 61 percent (dehulled). From these results, it appears that practically all of the rice that exited the separator with the straw would have been retrieved with the floaters had overall separation efficiency been 100 percent.

In tests with walker discharge material presorted to eliminate kernels, an average of 92 percent of the rice that went into the separator exited with the straw. This was considered quite high in as much as some loose kernels no doubt went in with the straw and others were undoubtedly so loosely attached to the heads that the slightest disturbance would have detached them. If loose kernels could have been completely eliminated from the straw, an even higher grain retention average would have been obtained.

In practice, where walker discharge samples are run as is through the separator, the failure to separate some loose kernels and the detachment and capture of other kernels previously attached to the heads would have offsetting effects on the accuracy of both walker and threshing loss estimates. The similarly high percentage figures for loose kernel separation efficiency and attached kernel retention obtained from the tests suggest that where the amounts of loose and attached grain in walker samples are similar in magnitude, errors of misassignment of threshing loss to walker loss and vice versa would not be serious. Results also suggest that dehulling may be unnecessary to obtain reasonbably accurate loss estimates.

Additional Comments

The water separator also has potential for use in field analysis of sieve discharge samples, particularly large ones. However, only two sieve samples were put through the separator in 1981, and no assessment of efficiency was made. Where sieve samples are small, which seems to be the case for some combines, sieve loss analysis can be performed quite readily with other types of equipment, particularly since prior head sorting is generally not required. A smaller sized water separator of appropriate design would be another alternative perhaps worth considering.

Although material is obviously very wet when it comes out of the separator, we believe this drawback is more than offset by the separator's apparently high efficiency and the elimination of the head presorting process its use affords.

After several years of work, it now appears that we have a reasonably reliable tool for use in future wild rice harvest research.

In 1982, we intend to try to develop an automated system for continuous retrieval of floating material. Such a system would reduce labor requirements and hopefully increase floater separation efficiency.

Table 1. Separator evaluation results expressed on an oven dry basis.

	Not dehulled (%)			Dehulled (%)		
	Sinkers	Floaters	Straw	Sinkers	Floaters	Straw
	Combine-harvested rice only, no straw					
Rep 1	78.4	21.6		86.9	13.1	
Rep 2	77.7	22.3		86.2	13.7	
Avg	78.1	22.0		86.6	13.4	
	Headless straw, combine-harvested green rice added					
Rep 1	83.7(99.7)*	12.6(54.0)	3.6	88.9(99.1)	8.4(60.6)	2.7
Rep 2	81.5(102.8)	11.6(52.2)	6.9	86.8(101.9)	8.0(60.6)	5.4
Avg	81.6(101.3)	12.1(53.1)	5.3	87.9(100.5)	8.2(60.6)	4.1
	Pre-sorted walker straw, no loose kernels assumed					
Rep 1	3.3	2.3	94.3	6.8	1.7	91.5
Rep 2	3.6	4.8	91.6	5.8	2.8	91.5
Avg	3.5	3.6	93.0	6.3	2.3	91.5

* Figures in parentheses are separation efficiency values for sinkers and floaters taken independently.

Wild Rice Processing Research

John Strait, Eric Donaldson, J. J. Boedicker

Wild rice processing research during 1981 was primarily directed toward the continued development of a continuous-flow parching process utilizing a parching medium consisting of a mixture of superheated steam with a small amount of hot air.

The laboratory-scale model parcher described in last year's report on processing research was used to further study the influence of operating variables upon the properties of the finished wild rice.

A full-size prototype of the laboratory-scale parcher was designed and constructed during the summer of 1981. The design of the full-size continuous-flow parcher was based upon data and results obtained from research with the laboratory unit. The prototype is located in a building constructed adjacent Kosbau Brothers' wild rice processing plant at Deerwood. The parcher was finished in time for two test runs to be completed near the end of the processing season.

Continuous-Flow Parcher

Figure 1 schematic drawing of the full-size continuous-flow parcher drawn approximately to scale to show the relative size and position of important parts.

Parching Chamber

The parching chamber is provided with inner and outer sheet metal surfaces on angle iron frames which form modular units that are bolted together. The spaces between the sheet metal surfaces are filled with insulation. Longitudinal angle iron members provide structural rigidity, bearing mounts and conveyor slideways. The parching chamber has three woven wire conveyors with rods three inches apart and No. 60 roller chain attached to the rods at the sides of the conveyors for drive purposes. Rotary air locks allow wild rice to enter and leave the parching chamber while restricting the flow of air or steam to or from the chamber.

The conveyors are driven by a variable speed drive system connected to the upper conveyor drive end. Roller chain interconnects the three conveyors and all are driven at the same speed.

Twelve agitators are located above the conveyor belts to impart random motion to the parching medium.

Feeder

The feed system includes primary and secondary feeder units. The primary feeder is adapted to hold up to about 1200 pounds of wild rice and to supply the secondary feeder with a fairly constant but limited supply of wild rice. The secondary feeder has a leveling device which provides a uniform layer of wild rice to the infeed air lock. A uniform layer of wild rice is, therefore, deposited onto the top conveyor belt.

Burner, Furnace and Heat Exchanger

A burner for propane provides heat energy for parching the wild rice. The burner is equipped with modulating controls for both gas and combustion air along with a control panel and interconnected safety devices in the propane supply line and in the duct through which the parching medium flows.

The furnace where combustion occurs is a steel box-like structure lined with a ceramic fiber refractory.

Hot gases from the furnace pass through a heat exchanger where heat is transferred to the parching medium. The heat exchanger has finned tubes and is manifolded so that the hot gases from the furnace pass the length of these tube banks before being exhausted to the atmosphere.

Thermostatic controls with a sensing thermocouple located downstream from the heat exchanger and in the path of flow of the parching medium modulate the propane and air to the burner to maintain a uniform temperature of the parching medium entering the parching chamber.

Fan and Ductwork

A fan equipped with a variable speed drive moves the parching medium through the system. The outlet of the fan is connected by insulated ductwork to the heat exchanger which in turn is connected by ductwork to the parching chamber. An insulated return duct connects the upper part of the parching chamber to the fan inlet. Means for recirculation of the parching medium is thereby provided.

Flow of Wild Rice Through the Parcher

The feeder system supplies a uniform layer of wild rice to the infeed air lock which is deposited on the top conveyor. The rice is discharged from the top conveyor onto the middle conveyor and then from the middle onto the lower conveyor. The lower conveyor discharges the parched wild rice through the outfeed air lock onto a belt conveyor which carries it into the processing plant.

Characteristics and Flow of the Parching Medium

Once equilibrium conditions are established, the parching medium would consist almost entirely of superheated steam. Since the pressure throughout the parcher is near atmospheric, superheated steam would be water vapor at a temperature greater than 212°F.

The parching medium or superheated steam is continuously recirculated through the parcher systems with provisions made for escape of the excess vapor resulting from water being evaporated from the wild rice.

The fan discharges into ductwork causing the superheated steam to pass over the exterior surfaces of the finned tubes in the heat exchanger. Here it is heated to a temperature of about 295°F. The superheated steam then enters the parching chamber below the level of the lower conveyor belt and passes upward through the wild rice on the conveyor belts while being acted upon by the rotating agitators. It then returns to the fan inlet through the return duct to be reheated to about 295°F.

Flow of Combustion Gases

The hot gases from the furnace enter the two bottom rows of tubes of the heat exchanger, pass the length of the finned tubes, returns through the next two rows of tubes and finally pass in the opposite direction through the top row of tubes. From there the gases enter a transition piece and flow upward through an exhaust pipe to the atmosphere.

Specifications

Capacity:

Design based upon parching capacity of 1000 pounds of green wild rice per hour

Parching chamber:

length 26 ft
height 8 ft other than at return duct outlet
width inside 51 1/8 in between sheet metal surfaces
outside 60 in at sheet metal surfaces
sheetmetal, 16 ga hot rolled

Conveyors:

Woven wire belts, steel, 84 x 84 mesh 20 ga wire with .234 in diameter rods on 3 in centers
Chain driven with RC 60, 3/4 in pitch roller chain
3 sections 48 in wide x approximately 49 ft long, 49 in C to C of chain, 50 1/4 in width overall
1 section same except 17 ft long for secondary feeder
Distance between conveyor pulley, 24 ft
Drive sprockets, 21-tooth taper lock

Fan:

36 1/2 in diameter wheel, backward curved blades, single width, single inlet
Variable speed V-belt drive with 10 HP 3 phase motor

Insulation:

Semi rigid board, fiberglass
4 1/2 in between sheet metal of parching chamber 1.6 lb density
3 in on ductwork and fan, 3 lb density with foil face

Burner and controls:

Eclipse Model 248 MVTA with modulating controls for both gas and combustion air
Safety controls for gas line, combustion gases and ducts
Prewired flame safety panel

Furnace:

Overall dimensions, 8 ft long x 28 1/2 in wide x 29 1/2 in high
Refractory, Ceramic fiber, Fiberwall screw anchored modules, 12 in x 12 in x 6 in thick, 7 lb/ft density
Ceramic fiberboard, 1 in thick, 24 lb/ft density in short connecting duct from furnace to heat exchanger

Heat exchanger:

27 finned tubes, 3 in diameter x 60 in long, 4 fins per inch, fins 3/4 in high
5 rows of tubes in staggered configuration
304 stainless steel headers and manifolds
Heat transfer capacity of at least 950,000 But/hr to steam heated from 230°F to 295°F at atmospheric pressure

Costs

Cost of materials, equipment and supplies was about $31,200.
Labor costs: 750 hrs for undergraduate student and about 400 hrs for a graduate student estimated 120 hrs machinist
Estimated total of all costs, $42,000

Operating Conditions

The parcher was designed to parch 1000 pounds of green wild rice per hour. This capacity is based upon a one-inch thickness of green rice on the upper conveyor and a resident time of 40 minutes in the parching chamber.

Based upon extensive research with the laboratory-scale continuous-flow parcher, the following operating parameters are considered to be most desirable:

1. Feed rate of 1000 lbs per hour

2. Temperature of the superheated steam to the parching chamber 295°F

3. Resident or parching time, 40 minutes

4. Flow rate of superheated steam would be adjusted to maintain temperature of steam in the return duct at about 230°F

Results

Two test runs were made with the full-size parcher at Deerwood. The results were very disappointing in that breakage of the kernels from hulling and scarifying was much greater than expected and inconsistent with results obtained with our laboratory model. Kernel strength in bending was noticeably less than that routinely achieved with comparable rice parched in the laboratory model.

Table 1 shows the characteristics of the wild rice and the results obtained from the two test runs at Deerwood and with samples from the same rice parched and hulled in the laboratory at St. Paul.

The first test run was completed on September 15 with an 8880 pound lot of K2 which had been harvested on Sept. 3. This material is listed as Lot 1 in Table 1. During the test run 210 pounds of K2 which had been harvested on September 9 and listed in Table 1 as Lot 2 was parched. Plant data showed about 20% broken kernels in Lot 1 while a sample from Lot 2 analyzed in the laboratory had about 24% broken kernels. Samples from Lots 1 and 2 shown in Table 1 as Lots 1a and 2a were parched and hulled in the laboratory resulting in 12.7% and 9.2% broken kernels respectively.

The parcher systems all functioned satisfactorily from a mechanical viewpoint. Flow rates were varied during the tests. A rate of 1000 pounds per hour was easily achieved. The parcher consumed 9.24 gallons of propane per 1000 pounds of green rice. This figure includes gas used during warmup and when the parcher was not running full at the beginning and end of the test. For comparison, some industry figures given to me varied from about 21 x 23 gallons of propane per 1000 pounds of green rice parched in rotary drum parchers.

A second test run was completed on September 23 with K2 wild rice which had been harvested on September 18 and run through the separator. The medium maturity portion of this wild rice is listed as Lot 3M in Table 1 and the heavy or mature portion is listed as Lot 3H. Lot 4 was a bag of K2 heavy rice harvested August 29 and frozen for later experimental use. Again, the data shows a high degree of kernel breakage. The figures shown in Table 1 were determined in the laboratory from samples collected at Deerwood. Samples from the same lots parched and hulled at Deerwood were parched and hulled in the laboratory. These samples are shown in Table 1 as Lots 3Ma, 3Ha and 4a. Kernel breakage was much lower in the laboratory processed rice.

Several adjustments were made during the second test and most of the test was run at a flow rate of under 1000 lbs per hour. Gas consumption based upon total running time was about 13 gallons of propane per 1000 pounds of green wild rice parched.

Research in Progress

We are making test runs with the laboratory model parcher to determine why results obtained at Deerwood were so different from those obtained in the laboratory. Wild rice parched in the prototype was weak and brittle tending to break into sliver-like pieces when it was hulled and scarified. Examination of parched kernels from the prototype under the microscope showed longitudinal stress cracks to be much more prevalent than normally found in rice parched in the model.

A continuous-flow parcher having a capacity of about 3000 pounds per hour was operated last fall by Landreth Farms. This parcher is similar in operating principles to the laboratory model and the prototype at Deerwood. Limited observations and data available at this time indicate that they did not experience kernel damage to the degree shown in Table 1 for the prototype parcher.

In summary, we feel confident that the prototype continuous-flow parcher is capable of a level of performance equal to that of the laboratory model. Progress has been made in determining the influence of specific operating variables to produce wild rice having characteristics similar to those associated with wild rice parched in the prototype. These studies will continue.

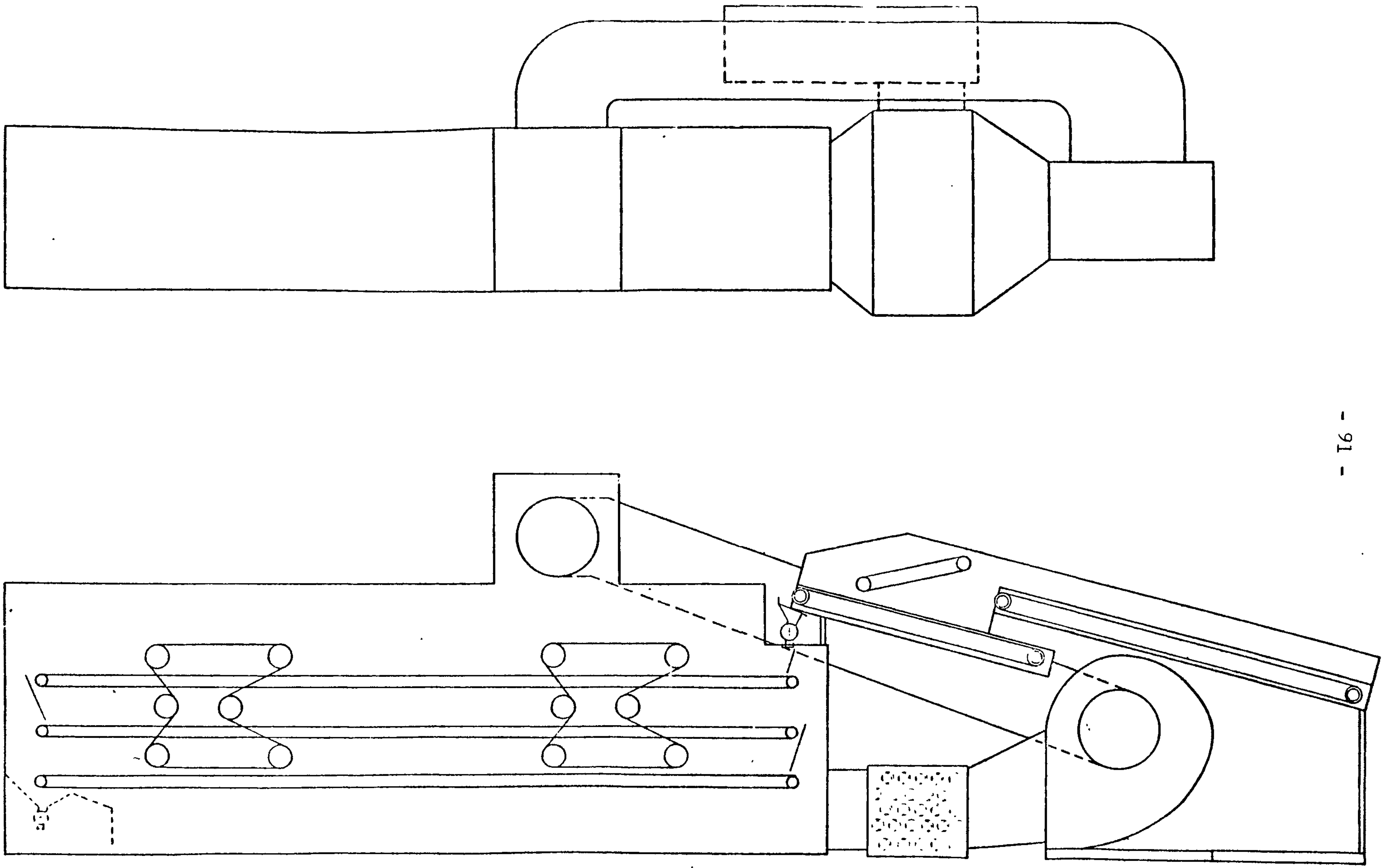

Figure 1. Schematic drawing of the full-size prototype continuous-flow parcher.

Table 1. Results of tests conducted on the prototype continuous-flow parcher at Deerwood and of tests with the same wild rice parched in the laboratory model.

Lot No.	Wild Rice	Date Harvested	Date Parched	Where Parched	Green Rice		Finished Rice	
					Weight Lbs	M.C. % W.B.	M.C. % W.B.	Broken %
1	K2	9/3	9/15	Deerwood	8880	40.1		20.0
2	K2	9/9	9/15	Deerwood	210	37.7	4.5	21.0
1a	Sample from Lot 1	9/3	9/17	Lab				12.7
2a	Sample from Lot 2	9/3	9/17	Lab				9.2
3M	K2 Medium	9/18	9/23	Deerwood	1225			35.0
3H	K2 Heauy	9/18	9/23	Deerwood	1000			24.3
4	K2 Heauy, frozen	8/29	9/23	Deerwood	67			24.0
3Ma	Sample from 3M	9/18	9/25	Lab		50.0	2.2	12.0
3Ha	Sample from 3H	9/18	9/25	Lab		43.6	3.0	9.7
4a	Sample from 4	8/29	9/25	Lab		37.0	3.1	6.7